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NECK FATIGUE AND COMFORT EFFECTS DUE TO THE EXTENDED WEAR OF LAW ENFORCEMENT REPRESENTATIVE HEAD-BORNE PERSONAL PROTECTIVE EQUIPMENT

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14. ABSTRACT
The objective of this study was to quantify the degradation of neck muscle fatigue and its affect on subjective comfort associated with the prolonged wear of head-borne personal protective equipment (PPE) with modified mass properties for durations up to 4 h. A National Institute of Occupational Safety and Health approved chemical biological radiological nuclear modified air-purifying respirator (APR) and military ballistic helmet were worn. Neck fatigue was measured as a function of neck muscle activity, neck strength, and neck strength stamina/endurance. Comfort was measured through a subjective comfort/fatigue survey. During the 4 h wear trial, volunteers were required to complete typical first responder tasks, perform a visual search task, and walk on a treadmill. Seventeen volunteers completed the study. These volunteers tested eight different respirator and helmet equipment configurations of varied mass properties. The configuration head-borne weight ranged from 2.25 to 6.05 lb. Also, the configuration center of gravity and moments of inertia covered a broad range. PPE wear time was shown to be a significant variable with regard to neck fatigue and discomfort responses. Differences associated with APR and helmet mass property variations were not found to be significant. However, significant effects were seen when compared to the no APR/no helmet configuration.

15. VOLUNTEER TERMS

Personal protective equipment	Mass properties	Neck fatigue
Discomfort	Respirator	Helmet

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PREFACE

The Department of Homeland Security, Science and Technology Directorate, sponsored the production of this material under Interagency Agreement No. M02398/ Contract No. HSHQDC-06-X-00394 with the U.S. Army Edgewood Chemical Biological Center. This work was started in July 2008 and completed in September 2009.

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CONTENTS

FIGURES

TABLES

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NECK FATIGUE AND COMFORT EFFECTS DUE TO THE EXTENDED WEAR OF LAW ENFORCEMENT REPRESENTATIVE HEAD-BORNE PERSONAL PROTECTIVE EQUIPMENT

1. INTRODUCTION

Respiratory protection requirements anticipated for law enforcement operations in response to a chemical or biological incident will likely precipitate the use of air purifying respirators (APRs) that meet or exceed National Institute of Occupational Safety and Health (NIOSH) Chemical, Biological, Radiological, and Nuclear (CBRN) certification standards. Many of the APR designs that currently meet these standards incorporate filter canisters, which are larger and carry more mass than their non-CBRN counterparts. These larger filters increase respirator system weights and create less than optimal distribution of mass when worn. Coupled with other head-borne equipment (e.g., helmets, riot control shields, communication devices, & protective hoods), the load on the head and neck may be significant. Ultimately, there is a limit as to how much mass can be supported by an APR and a wearer's head and neck before protection, comfort, and operational performance are adversely affected. Unfortunately, current personal protective equipment (PPE) standards do not set empirical limits for head-borne mass properties. These concerns are realistic and need to be considered due to the likelihood of prolonged wear and the diverse population that will rely on this equipment.

The primary purpose of a respiratory protective device is to protect a wearer's respiratory system from contaminants that may cause physical harm. However, law enforcement personnel must still be able to perform their occupational duties at an acceptable level during wear. Law enforcement officers may find themselves wearing respiratory protection while performing duties, such as crowd or perimeter control, tactical operations, crime scene investigation, rescue missions, and multiple other functions. Many of these missions could require the wear of various levels of head-borne PPE, both CBRN and non-CBRN, for extended periods of time. Ideally, the design of the entire head-borne system should be such that it can be worn for these extended periods with minimized discomfort or distraction. A head-borne system's mass property characteristics have the potential to greatly affect system acceptance, comfort, and usability.

In December of 2001, RAND Corporation (Santa Monica, CA) and NIOSH held a conference in New York City for emergency workers around the country who responded to the 1995 bombing of the Alfred E. Murrah Building in Oklahoma City, the September 11 attacks on the World Trade Center and the Pentagon, and the anthrax incidents that occurred during the fall of 2001. Through first-hand accounts from emergency responders, this meeting offered a unique look at the tremendous challenges forced on the emergency response profession, and offered recommendations for protecting emergency responders [1]. Of all personal protective equipment, respiratory protection elicited the most extended discussion across all of the professional panels. For almost all protective technologies, responders indicated serious problems with equipment not being comfortable enough to allow extended wear during demanding physical labor. It was frequently observed that current technologies require a tradeoff between the amount of protection they provide and the extent to which they are light enough, practical enough, and wearable enough to allow responders to do their jobs. While conference attendees were concerned about having adequate protection, many were even more concerned about equipment hindering them from accomplishing their rescue and recovery missions in an arduous and sustained campaign.

Head-borne mass has been an issue of concern within the aviation community, both fixed and rotary wing, for many years. In turn, the majority of the literature on this topic comes from the aviation community. The development of helmet mounted aviator displays and night vision systems have led to helmets, which carry more mass and have centers of gravity which are further from the head's natural center of gravity. Discomfort, fatigue, neck strain, and neck injury have all been listed as potential byproducts of excessive pilot helmet mass. The U.S.Navy and Air Force and European Air Force surveys in the 1980s documented neck injury rates of 50% or higher ranging from minor neck strain to cervical vertebral fracture [2-7]. A large portion of the available aviation community head-borne mass literature regards the affect of mass on the potential exacerbation of neck injury risk during crashes. These head-borne mass induced inertial loads are much less likely within the context of law enforcement CBRN activities. Additionally, some aviation community center of gravity location research and limitations have focused on fatigue, performance, and user acceptance. But the activities performed and equipment used does not translate well to the law enforcement CBRN mission. Therefore, any head worn mass limits set by the aviation community cannot be readily transferred to law enforcement standards. Outside of the aviation community, literature provides minimal information regarding limits for head-borne mass or the effects of head-borne mass.

In general, the physical properties of the head and neck have been well defined [8-16]. The center of the head is typically defined as the intersection of the Frankfurt, Frontal, and Mid-sagitial planes as shown in Figure 1. Data suggest the neck tends to fatigue more as head-borne weight is shifted away from the head's natural center of gravity (CG). Additional studies indicate that the neck's dorsal muscles are stronger and less susceptible to fatigue than other neck muscle groups and males have stronger necks than females. Therefore, it could be reasonable to assume that respirators should be positioned symmetrically and towards the front of the head and kept as light as possible.

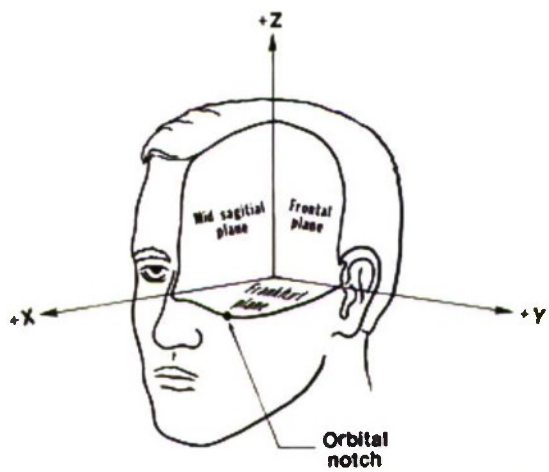

Figure 1. Head Anatomical Coordinate System

All current NIOSH CBRN approved APRs have filters located below (-Z axis) the Frankfurt plane and in front (+X axis) of the frontal plane. Unfortunately, other head-borne subsystems (e.g., helmets, night vision devices, helmet mounted displays, communication devices, etc.) are also loaded onto the head with a placement typically towards the front of the head. The relocation of CBRN filters toward the rear of the head to act as a counterbalance could be a potential relief by bringing the overall CG closer to that of the naked head. Therefore, this conceptual filter location is evaluated in this study.

This research project has been undertaken due to this paucity of law enforcement CBRN applicable mass property information. Without this study and its resultant experimental data, decisions concerning the design, development, and deployment of these CBRN systems, particularly over extended durations, will be severely limited. If these systems are fielded without having been tested on human volunteers, user safety, comfort, and performance may be compromised.

For the Department of Homeland Security (DHS), the National Institute of Standards and Technology (NIST) Office of Law Enforcement Standards (OLES) is facilitating research that may be used to support future law enforcement CBRN standards. The U.S. Army Edgewood Chemical Biological Center (ECBC) Respiratory Protection Branch, Aberdeen Proving Grounds, MD, with support from NIST OLES, has been pursuing multiple research efforts with the goal of developing quantifiable limits for future CBRN respiratory protecton standards. ECBC is the nation's principal research and development center for non-medical chemical and biological defense. ECBC contacted the U.S. Air Force Research Laboratory (AFRL) regarding AFRL's history of conducting human impact and fatigue testing. Much of this impact testing investigated the affects of variable helmet mass properties on the biodynamic response of male and female human volunteers exposed to vertical (+Gz) accelerations using the vertical deceleration tower [17-23], lateral +Gy [24] and frontal (-Gx) [25] impact using the horizontal impulse accelerator, and most recently the completion of a static neck fatigue program focusing on the fatigue associated with aviators wearing heavy flight helmets for durations up to 8 h [26]. Given ARFL's expertise and experience in this volunteer area, ECBC and AFRL agreed to collaborate on this research program investigating the human upper thorax fatigue, neck muscle fatigue and subjective discomfort effects associated with prolonged wear of possible law enforcement CBRN head-borne PPE while performing law enforcement applicable movements.

2. METHODS

2.1. Volunteers

An attempt was made to test equal numbers of men and women. A total of 24 volunteers (13 male, 11 female) participated in this study. Ten of the thirteen male volunteers were able to complete all eight 4 h sessions. Seven of the eleven female volunteers were able to complete all eight 4 h sessions. All of the volunteers who were unable to complete the program stated personal reasons, such as scheduling conflicts (e.g., job, school, etc.), as their reasons for termination. None reported the specifics of the study as reason for termination. Only the data from the 17 volunteers who completed all 8 sessions are included in this report.

Before acceptance into the study, volunteers completed a Medical Prescreen Questionnaire (Appendix A) that was reviewed by the medical monitor. Volunteer questionnaires were screened for any pre-existing factors that increased their risk for neck or thoracic muscle injury. Exclusion from the study was based on this risk and the best judgment of the medical monitor.

This test program was reviewed and approved by the Wright-Site Institutional Review Board and all volunteers provided informed consent to participate prior to any testing (Protocol F-WR-2007-0019-H). All volunteers were thoroughly briefed of the test program prior to entrance into the study. Following an opportunity to ask any questions regarding the program, the volunteers were asked to thoroughly read and sign the General Impact Consent Form (Appendix B) in order to document their agreement to participate in the test program. All volunteers were given the opportunity to withdraw from the study, or quit a test at their own discretion, at any time. Volunteers were compensated at the rate of $12.50 per hour and paid after each session.

Volunteers wore comfortable clothing (T-shirts, shorts, sweat pants etc.) and gym shoes. All volunteers attended an initial session used to introduce and familiarize them with the use of equipment, and answer any questions the volunteer may have. Anthropometric measurements were collected at this initial session. Table 1 lists the summary anthropometry and age for all volunteers completing this study. All anthropometry is listed in centimeters.

2.2. Independent variables

2.2.1. Headgear Configurations: 8 different headgear configurations were tested in this study (Table 2). Seven of the configurations included headgear (equipment donned on the face/head). Filter placement was varied to represent potential future respiratory protection concept filter locations. The testing sequence was counterbalanced (Latin Square design), yet all volunteers began the study with a baseline configuration wearing no gear (Configuration A). Photographs of all headgear configurations are included in Appendix C.

Table 1. Volunteer Anthropometry

Dimensions in Centimeters	Females				Males			
	Mean	**Std. Dev.**	**Min.**	**Max.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Age (years)	22.43	2.23	20	26	22.50	6.64	18	40
Weight (kg)	75.27	19.35	59.95	116.86	88.53	20.09	66.32	126.09
Height	164.77	4.80	158.10	172.30	179.60	4.55	174.40	187.30
Chest Circumference @ Scye	97.69	12.38	86.00	122.80	103.90	10.54	93.40	126.30
Chest Circumference	100.64	14.24	89.70	130.70	102.18	11.99	88.50	128.50
Biacromial (Shoulder) Breadth	38.11	0.67	37.40	39.50	41.17	2.63	38.10	47.40
Bideltoid Breadth	47.39	4.70	42.90	57.00	49.82	3.17	45.00	53.60
Chest Depth	27.16	4.78	22.50	37.00	26.06	3.42	21.40	33.70
Interscye Distance	34.14	3.68	30.40	41.30	36.49	2.96	32.70	41.90
Shoulder Length	12.97	0.98	11.50	14.60	15.85	4.20	12.00	25.00
Sitting Height	88.16	3.13	82.40	92.20	92.61	2.51	88.20	95.60
Overall Neck Length (Measured from Occiput to T1)	13.99	1.13	12.10	15.70	13.75	1.64	11.30	16.10
Face Length	10.99	0.42	10.50	11.50	12.48	0.60	11.10	13.20
Bizygomatic Breadth (Face Breadth)	13.26	0.29	12.80	13.60	14.22	0.46	13.40	14.90
Bigonial Breadth	9.61	0.27	9.30	10.10	10.92	0.80	9.50	12.00
Head Length	19.44	0.74	18.50	20.60	19.89	0.71	18.20	20.70
Head Breadth	14.74	0.30	14.30	15.10	15.53	0.48	14.90	16.20
Head Circumference	56.27	1.28	54.00	58.10	57.71	1.51	54.50	60.00
Neck Circumference at mid-cervical spine	33.41	2.88	30.50	39.10	38.71	2.33	34.60	42.50
Base neck Circumference including Trapezius Musculature	44.31	2.80	38.90	47.60	48.00	3.54	41.40	53.80
Neck Base Circumference (CAESAR Method)	44.50	2.14	40.50	46.70	44.29	9.87	17.50	51.00
Bitragion-Submandibular Arc	28.37	1.72	26.60	31.60	30.79	1.52	27.90	33.00
Bitragion-Menton Arc	30.91	1.46	29.30	33.90	32.92	1.25	31.00	35.00

Table 2. Headgear Configurations

	Headgear Configuration		
Configuration	Helmet	Respirator	Filter Placement
A	No	No	None
B	PASGT	Yes	Left Side Mask
C	PASGT	Yes	Front of Mask
D	PASGT	Yes	Back of Helmet
E	None	Yes	Left Side Mask
F	None	Yes	Front of Mask
G	PASGT	None	Back of Helmet
H	PASGT	Yes	Left Upper Arm

Helmet: The Personal Armor System Ground Troops (PASGT) was used in this study (Figure 2). This helmet is a standard infantry combat helmet worn by the U.S. Military. The shell is made from 19 layers of Kevlar, and offers protection against fragmentation and ballistic threats and meets the requirement of MIL-STD-662 E. The three sizes of helmets used in this study weighed 3.15 (small), 3.49 (medium), and 3.71 (large) lb.

Figure 2. Personal Armor System Ground Troops (PASGT) Helmet

The following chart (Table 3) was used to determine the appropriate size helmet for each volunteer. This chart comes from Natick Pamphlet 70-2 (July 2000) entitled, "This is Your Ballistic Helmet." If a volunteer fell on a dividing line, the larger of the two sizes were chosen. This pamphlet was also used to adjust the helmet so it sat on the head correctly.

Table 3. Helmet Sizing Chart

	Head Length (in.)	Head Width (in.)	Head Circumference (in.)
X-Small (XS)	Up to 7.1	Up to 5.6	Up to 21.1
Small (S)	7.1 to 7.6	5.6 to 6.0	21.1 to 21.9
Medium (M)	7.6 to 7.9	6.0 to 6.3	21.9 to 22.7
Large (L)	7.9 to 8.3	6.3 to 6.5	22.7 to 24.0
X-Large (XL)	8.3 to 8.8	6.5 to 7.1	24.0 to 26.0

Two females wore the Small helmet, four females wore the Medium helmet, and one female wore the Large helmet. Six males wore the Medium helmet, four males wore the Large helmet, and no males wore the Small helmet. None of the volunteers wore the X-Small or X-Large helmets.

Respirator: The Mine Safety Appliance Co. (MSA) Millennium® CBRN Gas Mask/Respirator (P/N 10051286) was used in this study (Figure 3). The respirator effectively removes harmful gases, vapors and particulates from the air so that the user can confidently breathe safely. This respirator is based on the MCU-2/P military gas mask. The three sizes (small, medium, large) of respirators used in this study weighed 1.14 (small), 1.22 (medium), and 1.25 (large) lb. without a canister. The respirators consist of the following components:

- Dual-canister mount allowing weapon sighting from either shoulder
- Flexible 1 piece polyurethane lens with wide field of vision bonded to the rubber face-piece
- Elastic 6 point head harness
- Internal nosecup with drinking tube and 2 check valves that reduce lens fogging
- Standard mechanical speaking diaphragm
- NBC Hood - Butyl-coated nylon hood (not used in this study)

The MSA canister used in this study was the MSA P/N 10046570. This canister contains chemical sorbents and a P100 filter to attract, retain, and neutralize contaminants. The canister weighed approximately 1.00 lb. To negate the affect of breathing resistance as a variable, the canister was not employed for breathing. Instead, the respirator check-valves (inhalation and exhalation) were modified to allow airflow through the valves and in turn consistent inhalation resistance for all equipment conditions.

Figure 3. Mine Safety Appliance Co. (MSA) Millennium® Respirator

The combined weight of the respirator and canister was approximately 2.25 lb.

Typically, a respirator fit-tester is used to determine which respirator size provides a user with the best fit based on the proper seal. For this study, a NIOSH approved sizing chart (Figure 4) was used as checking the proper seal was not possible due to the reconfiguring of the respirators to allow airflow through the check-valves. If a volunteer fit into two possible sizes, the test conductor determined the final size through the following two subjective criteria:

- Location of the eyes: Ideally the eyes would be halfway between the top and bottom of the lens.
- Interference of the seal at the hairline: The seal should not overlap the wearer's hairline.

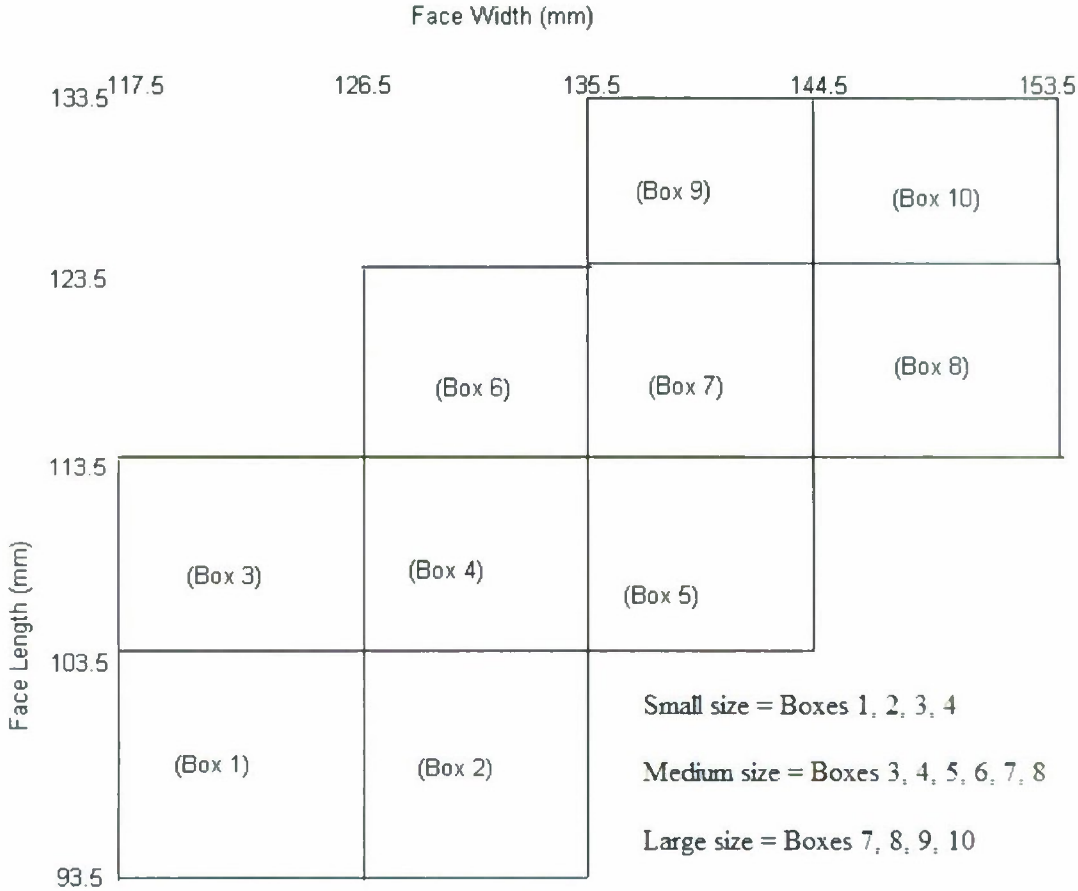

Figure 4. Respirator Sizing Chart

2.2.2. Mass properties: The weight, CG, and principal moments of inertia (PMOI) of the 7 head gear configurations (Cells B-H) that were tested for this program were measured using the methods described in a report by Albery, et al. [27]. All configurations were measured on the Large Advanced Dynamic Anthropomorphic Manikin (ADAM) head. All CG are with respect to the ADAM head anatomical axes system, the ADAM head head/neck joint axes system, and the helmet-based axes system. The principal moments of inertia are about the test articles' CG. The mass properties results are documented in Table 4.

The landmarks on the manikin head and helmet surfaces that define the head axes systems and helmet axis systems are marked before mass properties testing begins. Landmarks on the manikin head correspond to human head landmarks used to identify the head anatomical and head/neck joint coordinate systems.

Landmarks used to define the head anatomical axis system for the manikin head are the right tragion, left tragion, sellion, and right infraorbitale. The tragions are the points located at the notch just above the tragus of each ear. The sellion is the greatest depression of the nasal root in the midsagittal plane and the right infraorbitale is the lowest point on the inferior margin of the right eye socket. The Y axis extends from the right tragion to the left tragion and the X direction is along the line normal to the Y axis and passing through the right infraorbitale. The Z axis direction is obtained by taking the cross product of X and Y. The origin is located at the intersection of the Y axis and a normal passing through the sellion.

Landmarks used to define the head/neck joint axis system for the manikin head are the left and right ends of the head/neck joint (pin), bolt holes on the back of the skull, and the center of the head/neck joint (pin). The Y axis extends from the upper right skull cap hole to the upper left skull cap hole. The Z axis extends from the lower right skull cap hole to the upper right skill cap hole. The X axis is obtained by taking the cross product of Y and Z. The axes are then translated to the head/neck joint center (center of the head/neck pin). The manikin head axes systems are illustrated in Figure 5.

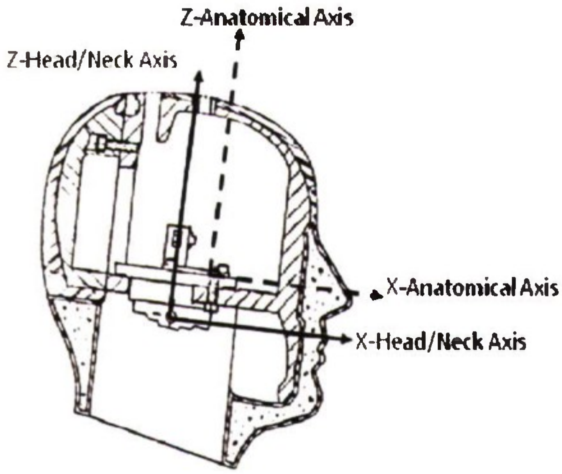

Figure 5. Manikin Head Coordinate Systems

2.3. Dependent Variables

2.3.1. Neck Muscle Strength and Stamina: A neck strength device was used to measure neck strength (100% Maximum Voluntary Contraction [MVC]) and endurance (70% of MVC). This device consisted of an adjustable chair (up/down), adjustable leg/foot rest (in/out), lap belt, and adjustable miniature load cell (up/down). The miniature tension/compression load cell used for this program was a Honeywell Model: 31/1432-04-02, Range: 250 lbs, Excitation: 10.0 VDC, Output: 2.0 MV/V.

An attempt was made to isolate the neck muscles. Volunteers' lower legs and feet were placed on an adjustable and extended foot rest so they could not be used to brace or push. Likewise, volunteers' arms were hung at their sides so they could not brace or push. The volunteers were secured in the chair with the lap belt. The seat back was adjusted so the top edge was level with the top of the shoulders. The helmet was removed and a head harness was donned. An adjustable strap was connected from the front of the head harness to the load cell. The load cell height was adjusted so the strap was level or slightly elevated when pulled taut. The strap length was adjusted to ensure the cervical spine was straight. The load cell measured the force the volunteer pulled on the strap in extension (Figure 6).

Figure 6. Volunteer in Neck Strength Device

Three 100% MVCs were collected at both the beginning and end of the test session to measure the volunteer's neck strength. The volunteer was instructed to pull as hard as he or she could for a length of no more than 4 sec with 1 min of rest-time in between each MVC. The largest of the 3 MVCs was considered the actual MVC for the day. The neck endurance target was then 70% of that MVC. The endurance runs were conducted at the end of each hour. The volunteer was instructed to hold 70% +/- 2 lb. for as long as they could or for a maximum of 3 min. If at any time the test conductor felt the volunteer was not consistently able to stay within the range, the volunteer was instructed to stop. The volunteer could also voluntarily stop pulling at any time if it became too difficult or painful.

Visual and auditory feedback was provided while the volunteer pulled. For the strength (100% MVC) pulls, a computer monitor displayed the real-time force-plot from the load cell. For the endurance (70% of MVC) pulls, the target force range (70% ± 2 lb.) was displayed on the monitor and a voice command was provided. The monitor displayed 3 horizontal lines (Figure 7). The middle, blue line represented the target (70% MVC), the top, green line as the upper extreme (70% + 2 lb.), and the bottom, red line as the lower extreme (70% - 2 lb.). The voice command instructed the volunteer to go "EASY" if the volunteer pulled too hard or "HARDER" if the volunteer was not pulling hard enough to stay in the targeted range.

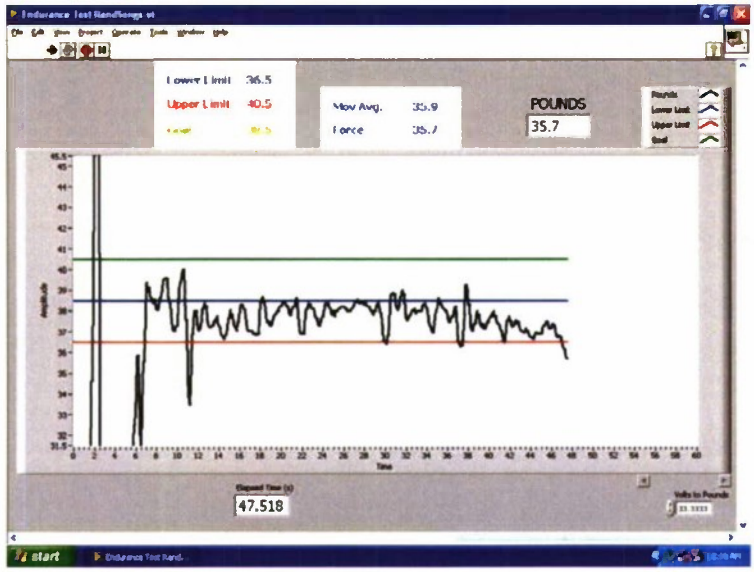

Figure 7. Display during Endurance Pull

2.3.2. Muscle Activity: Electromyography (EMG) has been widely used to investigate muscle fatigue. EMG has become an increasingly popular and useful tool to quantify muscle strength and fatigue. Typically, a muscle group is isolated, and monitored for strength and fatigue by measuring relative changes in EMG root mean square amplitudes and decreases in EMG frequency content. With surface EMG, fatigue is generally accompanied by increases in amplitude [28-29] and shifts in the EMG spectrum to lower frequencies during prolonged contractions [29-34]. Amplitude is a function of both the number of motor units recruited and the frequency of their discharge. The frequency components of EMG are a function of the duration of motor units' action potentials, the geometry of the surface electrodes, the degree of motor unit synchronization, and the conduction velocity of action potentials on the sarcolemma [35]. Well prescribed methods exist for the use of EMG to quantify fatigue, but their efficacy in dynamic environments is uncertain [36].

Surface EMG was used in this study in an attempt to quantify the target muscles' level of fatigue (Figure 8). A DelSys® Bagnoli™ 8-channel desktop EMG system, and parallel-bar active EMG electrodes (model DE-2.1) were used for this program. EMG was collected at 1000 Hz from the left and right pairs of the upper trapezius muscle at the level of the splenius capitus. The volunteers' skin and electrodes were prepped using alcohol prep pads prior to electrode placement. DelSys® Electrode Interface pads (double sided tape) were used to affix the sensors to the skin so the electrodes were perpendicular to the muscle fibers. The sensors were placed perpendicular to the muscle fibers just prior to any strength and endurance tests. If needed, medical tape was used on the back of the sensor to hold it in place. A reference sensor was placed on the left olecranon (elbow) or acromion process (lateral side of shoulder). Muscle activity was monitored and recorded during the strength and endurance tests using a DelSys® Bagnoli-8 EMG system.

All data were initially examined using the DelSys® EMG Works Analysis 3.5 Program. The data were then converted to .csv format and delivered to USAFRL, Brooks City Base, San Antonio, TX for detailed analyses.

Each .csv was then stripped of headers for ease of processing ultimately consisting of four columns of data corresponding respectively to sample time, channel #2 (left trap), channel #3 (right trap), channel reference. Four programs (8 total) were written for each gender to help with processing the data. Program1 found the Root Mean Square (RMS) for every configuration (A-E) at every hour (0-4) at each power (70 or 100%) for both left and right traps. It then found the change from hour to hour for all combinations and stored the information. Program 2 did the same for Max frequency, and recorded frequency shift across time. Note that 60 and 180 Hz filters were used to remove the 1st and 3rd harmonics of the 60 Hz AC power source used during data collection. Programs 3 (RMS) & 4 (freq) averaged the data for each configuration for 1-2, 2-3, 3-4, and 1-4 h at 70%. At 100%, only hours 0-4 were examined as those were the only times the 100% data were taken. After the data were processed in Matlab, SPSS was used to run descriptive, omnibus, and t-tests on relative data.

Electrodes

Figure 8. Electrode Placement

2.3.3. Perceived Discomfort: To determine whether a correlation existed between head gear configurations and perceived discomfort, volunteers completed a computerized comfort survey (Appendix D) near the end of every hour throughout the 4 h session. Volunteers also completed this survey at the beginning and end of each session. A 7 point scale was used ranging from no discomfort to severe discomfort for most of the questions. The volunteers rated their comfort level for four different body regions: head, neck, upper and mid back (grouped), and lower back. The volunteers remained seated while taking the survey. The survey was displayed on a 19" computer monitor. An example from the survey is shown in Figure 9. A mouse was used to select the perceived comfort level.

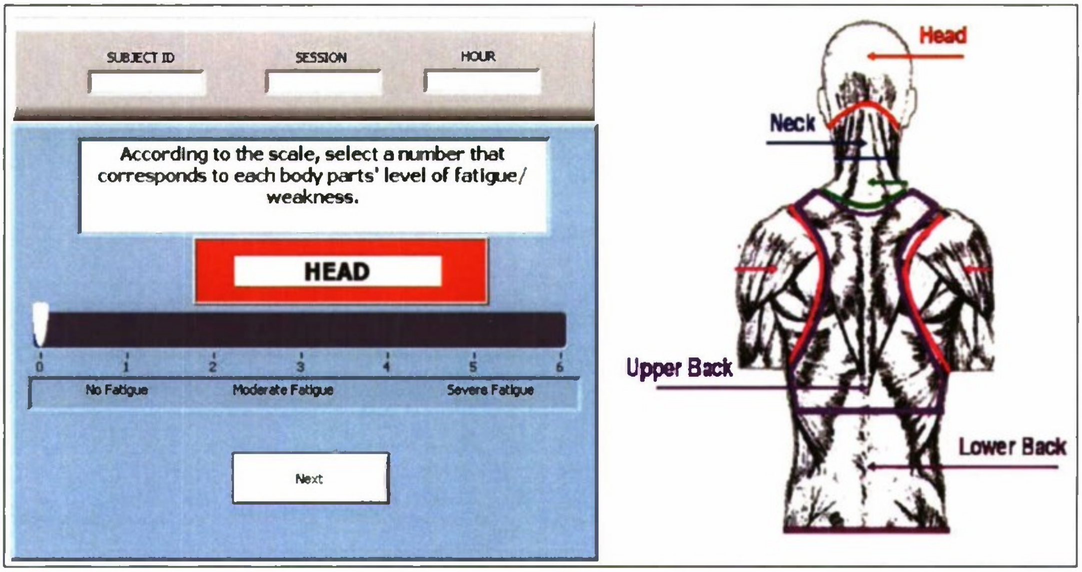

Figure 9. Example from Comfort Survey

2.3.4. Common Tasks: All volunteers completed representative law enforcement 1st responder tasks throughout every hour in addition to the dependent variables previously described. These tasks occupied approximately 30 min of each hour. These tasks included walking (on a treadmill at different rates and inclines), standing and sitting, kneeling and searching, standing and searching, pistol handling (drawing, aiming, holstering) and performing a visual search task. Each volunteer performed these tasks every hour in a prescribed manner. The Test Conductor's Checklist (Appendix E) lists the tasks in the order they were performed for each session. The volunteers spent 30 min of each hour walking on a treadmill at speeds of 2-3 mph. and inclines up to 6% (including 9 min of rest breaks), 8-10 min of each hour performing mobility tasks such as sitting, standing, kneeling, searching, pistol handling etc., 5 min of each hour completing the visual search task, and up to 5 min of each hour completing the neck muscle endurance and strength measures, and comfort/fatigue survey. The rest of each hour was spent donning/doffing gear and going from station to station.

2.3.4.1. Visual Search Task: Near the end of each hour, volunteers performed a classic visual search task. The volunteers sat in front of a large (6 ft. wide x 4 ft. tall) rear projection screen (Figure 10). The seat was adjusted so the volunteers' eyes were 3 ft. from the screen and centered in the screen. This placement ensured the volunteers had to move their head and neck to search and find the target. The task was a timed, two-alternative, forced choice task where the target was either randomly present or not. The target was a red circle amongst a screen full of distracters (100 red squares and 100 blue circles). Each of the 30 screen shots were shown for up to 7 sec each. If no choice was made within 7 sec, the next screen was shown after a 3 sec delay. If the volunteer made a determination that the target was either present or not before the 7 sec had elapsed, the screen remained blank for the remainder of the 7 sec plus the 3 sec delay. This task continued for 5 min. This allowed for the measurement of reaction time, hits, false alarms, misses, and correct rejections. Note the red circle in the lower right corner of Figure 11.

Figure 10. Volunteer Completing the Visual Search Task

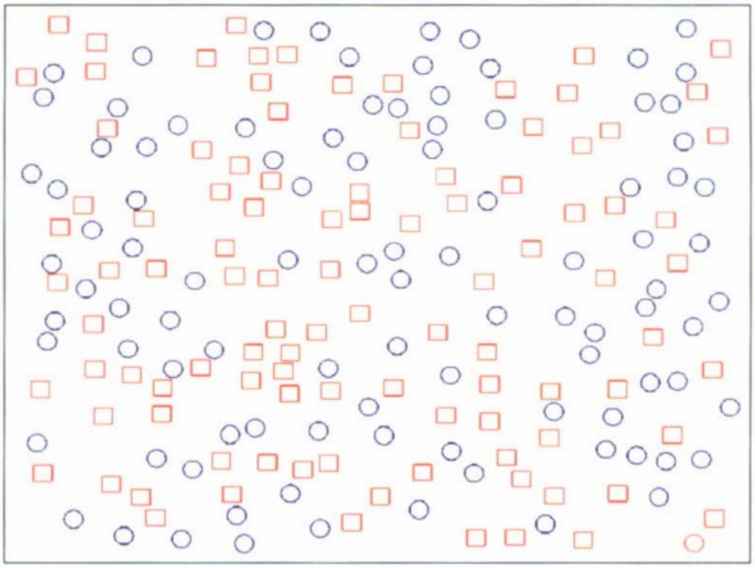

Figure 11. Example of a Visual Search Task (notice the red circle in the lower right corner)

2.3.4.2. Walking on Treadmill: Volunteers walked on the treadmill for 21 min to begin each hour wearing the head gear configuration for that session (Figure 12). Immediately following the pre-test 100% MVC, and each endurance (70% of MVC) pull, volunteers were asked to walk on the Star Trac P-TR treadmill at a rate of 2 mph, 2 mph with a 6% incline, or 3 mph for 7 min at each level. At the end of the 7 min, the volunteers took a 3 min rest. The volunteers were asked to place their hands on the treadmill's heart rate monitor located on the forward handrail as soon as stepping on the treadmill, then again after 2.5 min, 5 min, and after the 7th minute. The heart rates were recorded and checked against the treadmill's interactive heart rate chart to assure they were within the treadmill's recommended limits (Figure 13). Nearly all volunteers remained below the 65% zone, and none got into the 75% or higher zones.

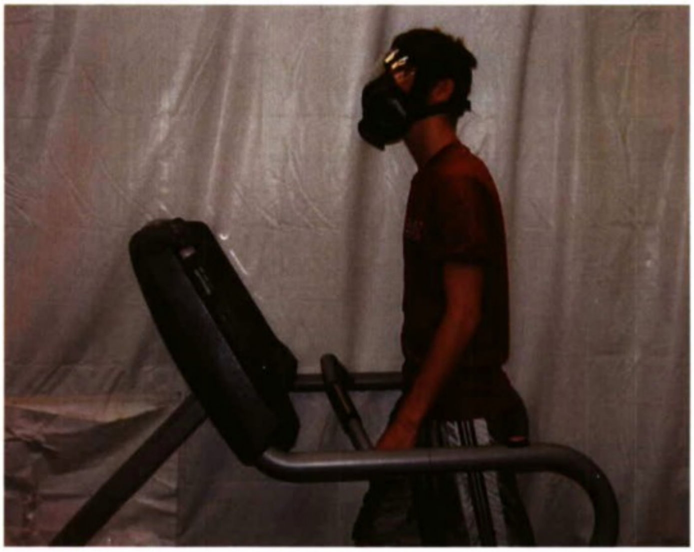

Figure 12. Volunteer Walking on Treadmill

AGE	BEATS/MINUTE		
	65%	75%	90%
20	130-150	150-180	180-200
25	127-146	146-175	175-195
30	123-143	143-171	171-190
35	120-139	139-166	166-185
40	117-135	135-162	162-180
45	114-131	131-157	157-175
50	110-128	128-153	153-170
55	107-124	124-148	148-165
60	104-120	120-144	144-160
65	101-116	116-139	139-155

65% - 75% = FAT LOSS TRAINING RANGE

75% - 90% = Cardiorespiratory Training Range

Figure 13. Treadmill Heart Rate Training Chart Specifications

2.3.4.3. Draw, Sight, and Holster a Pistol: One of the routine law enforcement first responder tasks (called "Controlled Movements" in the Test Conductors Checklist – Attachment 5) completed every hour following the Visual Search Task was the draw, sight, and holster a pistol task (Figure 14). Volunteers were handed a training rubber M9 9 mm pistol with a laser mounted on the barrel. For 2 min, the volunteer was verbally directed by the test conductor to draw, sight for 5 sec (aim laser at target), and holster the pistol (for approximately 2 sec) at the 6 targets (Left, Right, Up, Down, Over the Right Shoulder, Over the Left Shoulder). A typical command went, "draw, right shoulder, holster, left, holster, up, holster, etc."

Figure 14. Draw, Sight, Holster Pistol Task

2.3.4.4. Standing with Head Motions: Standing in place, the volunteer was directed to slowly turn his/her head and look at one of the 6 targets (Left, Right, Up, Down, Over the Right Shoulder, Over the Left Shoulder) for 5 sec. The volunteer was then directed to slowly turn his/her head and look at another one of the 6 targets for 5 sec, and so on. This task continued for 2 min.

2.3.4.5. Kneeling with Head Motions: On all fours, the volunteer was directed to slowly turn his/her head and look at one of the six targets (Left, Right, Up, Down, Over the Right Shoulder, Over the Left Shoulder) for 5 sec (Figure 15). The volunteer was then directed to slowly turn his/her head and look at another one of the 6 targets for 5 sec, and so on. This task continued for 2 min.

Figure 15. Volunteer Kneeling Performing Head Motions

2.3.4.6. Repeatedly Sit/Stand: The volunteer stood in front of a folding chair and was directed to sit and stand repeatedly holding each position for 5 sec (Figure 16). This task continued for 2 min.

Figure 16. Volunteer Performing Sit/Stand Task

3. RESULTS

3.1. Mass Properties

The 7 head gear configurations were measured on a size Large, Advanced Dynamic Anthropomorphic Manikin (ADAM) manikin head with known mass properties to determine the CG shift when the gear was worn. The configurations' mass properties data along with the manikin head data are listed in Tables 4 through 8. The CG data were recorded with respect to the manikin head's anatomical coordinate system (Frankfort plane), and the manikin's head/neck joint (Figure 5).

Table 4. Center of Gravity in Manikin Head Anatomical Axes System

CONFIGURATION	CENTIMETERS			INCHES		
	X	Y	Z	X	Y	Z
Cell B: Helmet, Mask, Canister on Left, on ADAM Manikin Head	0.01	0.60	2.57	0.00	0.24	0.99
Cell C: Helmet, Mask, Canister in Front, on ADAM Manikin Head	0.81	-0.25	2.84	0.32	-0.10	1.12
Cell D: Helmet, Mask, Canister on Baek of Helmet, on ADAM Manikin Head	-1.94	-0.05	3.69	-0.77	-0.02	1.45
Cell E: Mask, Canister on Left, on ADAM Manikin Head	0.79	0.73	1.04	0.31	0.29	0.41
Cell F: Mask, Canister in Front, on ADAM Manikin Head	1.43	-0.03	1.41	0.56	-0.01	0.56
Cell G: Helmet, Canister on Baek of Helmet, on ADAM Manikin Head	-3.06	0.30	3.71	-1.21	0.12	1.46
Cell H: Helmet, Mask, Canister on Upper Arm, on ADAM Manikin Head	-0.9	-0.04	3.25	-0.35	-0.02	1.28
ADAM Manikin Head	-1.40	0.25	2.51	-0.55	0.10	0.99

Table 5. Center of Gravity in Manikin Head/Neck Joint Axes System

CONFIGURATION	CENTIMETERS			INCHES		
	X	Y	Z	X	Y	Z
Cell B: Helmet, Mask, Canister on Left, on ADAM Manikin Head	1.86	0.86	4.88	0.73	0.34	1.92
Cell C: Helmet, Mask, Canister in Front, on ADAM Manikin Head	2.61	-0.05	5.32	1.03	-0.02	2.10
Cell D: Helmet, Mask, Canister on Baek of Helmet, on ADAM Manikin Head	-0.25	0.28	5.66	-0.10	0.11	2.23
Cell E: Mask, Canister on Left, on ADAM Manikin Head	2.93	0.90	3.51	1.15	0.36	1.38
Cell F: Mask, Canister in Front, on ADAM Manikin Head	3.46	0.16	4.02	1.36	0.06	0.99
Cell G: Helmet, Canister on Baek of Helmet, on ADAM Manikin Head	-1.35	0.51	5.47	-0.53	0.20	2.15
Cell H: Helmet, Mask, Canister on Upper Arm, on ADAM Manikin Head	0.85	0.26	5.41	0.34	0.10	2.13
ADAM Manikin Head	0.50	0.52	4.58	0.20	0.20	1.80

Table 6. Principal Moments of Inertia

CONFIGURATION	PRINCIPAL MOMENTS OF INERTIA (KG-CM^2)				PRINCIPAL MOMENTS OF INERTIA (LBS-IN^2)		
	X	Y	Z		X	Y	Z
Cell B: Helmet, Mask, Canister on Left, on ADAM Manikin Head	618.68	653.22	364.47		211.42	223.22	124.55
Cell C: Helmet, Mask, Canister in Front, on ADAM Manikin Head	659.36	716.83	363.31		225.32	244.96	124.15
Cell D: Helmet, Mask, Canister on Back of Helmet, on ADAM Manikin Head	607.29	650.73	529.92		207.52	222.37	181.09
Cell E: Mask, Canister on Left, on ADAM Manikin Head	232.09	566.55	419.63		79.31	193.6	143.4
Cell F: Mask, Canister in Front, on ADAM Manikin Head	200.66	515.66	476.36		68.57	176.21	162.78
Cell G: Helmet, Canister on Back of Helmet, on ADAM Manikin Head	353.6	547.78	478.89		120.8	187.19	163.64
Cell H: Helmet, Mask, Canister on Upper Arm, on ADAM Manikin Head	458.51	499.99	334.33		156.68	170.86	114.25
ADAM Manikin Head	351.29	546.87	484.48		120.04	186.88	165.56

Table 7. Configuration Weights

CONFIGURATION	WEIGHT (LBS)		WEIGHT (KG)
Cell B: Helmet, Mask, Canister on Left, on ADAM Manikin Head	15.06		6.85
Cell C: Helmet, Mask, Canister in Front, on ADAM Manikin Head	15.06		6.85
Cell D: Helmet, Mask, Canister on Back of Helmet, on ADAM Manikin Head	15.21		6.91
Cell E: Mask, Canister on Left, on ADAM Manikin Head	11.55		5.25
Cell F: Mask, Canister in Front, on ADAM Manikin Head	11.55		5.25
Cell G: Helmet, Canister on Back of Helmet, on ADAM Manikin Head	13.98		6.35
Cell H: Helmet, Mask, Canister on Upper Arm, on ADAM Manikin Head	14.07		6.40
ADAM Manikin Head	9.35		4.25

Table 8. Component Weights

COMPONENT WEIGHTS	WEIGHT (LBS)		WEIGHT (KG)
Large Mask	1.23		0.56
Medium Mask	1.22		0.55
Small Mask	1.14		0.52
Large Helmet	3.71		1.69
Medium Helmet	3.49		1.59
Small Helmet	3.15		1.43
Canister	1.00		0.45

In terms of worse case or best case mass properties, configuration "G" resulted in the greatest CG shift rearward and upward, and configuration "F" resulted in the greatest CG shift forward and downward. However, these configurations did not include all possible gear (helmet and respirator with filter). Of these configurations, configuration "D" resulted in the greatest CG shift rearward and upward, and configuration "C" resulted in the greatest CG shift forward. The configurations resulting in the least amount of CG shift and including all the gear were configuration "H" and configuration "B."

3.2. Neck Muscle Strength and Endurance

The neck strength device was used to collect the volunteer's neck strength (100% MVC) at the beginning and end of each test session and the volunteer's neck endurance (70% MVC duration) at the end of every hour throughout the test session (4 h). The neck strength and endurance data were first analyzed univariately by combining repeated measures data into means to account for the correlated data from the same volunteer. The male volunteers had significantly higher 100% MVC's than the female volunteers (p-value < 0.0001) for both the pre-test and post-test. The males' pre-test 100% MVCs ranged from 29.4 to 86.2 lbs. (mean = 59.0). The males' post-test 100% MVCs ranged from 40.2 to 82.9 lbs. (mean = 58.3). The females' pre-test 100% MVCs ranged from 20.0 to 50.6 lbs. (mean = 36.4). The females' post-test 100% MVCs ranged from 17.5 to 53.8 lbs. (mean = 35.9). There was a high correlation found between neck strength and neck circumference at the mid-cervical spine, $r = 0.794$ for pre-test and $r = 0.849$ for post-test. There was a moderate correlation found between neck strength and weight, $r = 0.610$ for pre-test and $r = 0.674$ for post-test. No significant differences were found between the pre- and post-test strength pulls as demonstrated by the nearly identical 100% MVCs (Figure 17).

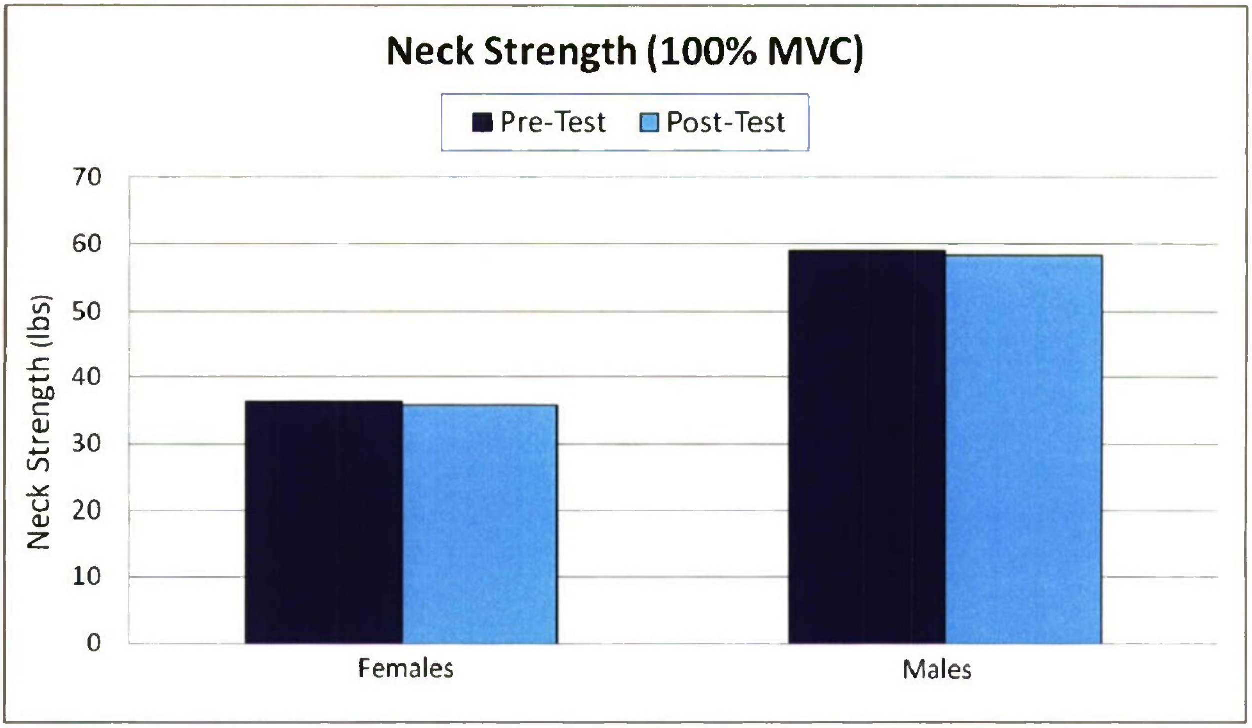

Figure 17. Mean MVCs for Male and Female Volunteers

A t-test was performed on the neck stamina data, which were measured by the volunteers' ability to maintain their 70% MVC (Table 9, Figure 18) by gender for each headgear configuration. Although not statistically significant, the female volunteers had longer average endurance times than the male volunteers for all configurations. This may be an indication that the male volunteers gave a truer 100% MVC at the beginning of the session. A low correlation was found when comparing neck stamina or endurance and neck circumference at mid-cervical spine (r = -0.392) and weight (r = -0.388). This is not surprising based on the high to moderate correlations seen above with neck strength and neck circumference and weight. Although configuration "A" had the longest average endurance time (42.8 sec), it was not statistically different from the other 7 configurations based on an analysis of variance (ANOVA) (*p*-value = 0.3412).

Table 9. Male and Female Mean Endurance Times Across All 4 h

Configuration	Males (sec)	Females (sec)	p-value
A	39.1	48.2	0.7168
B	23.2	31.3	0.2663
C	25.4	37.4	0.3014
D	24.3	31.2	0.4096
E	23.4	36.3	0.1853
F	22.9	30.1	0.3388
G	19.8	35.1	0.1767
H	21.8	35.2	0.2047

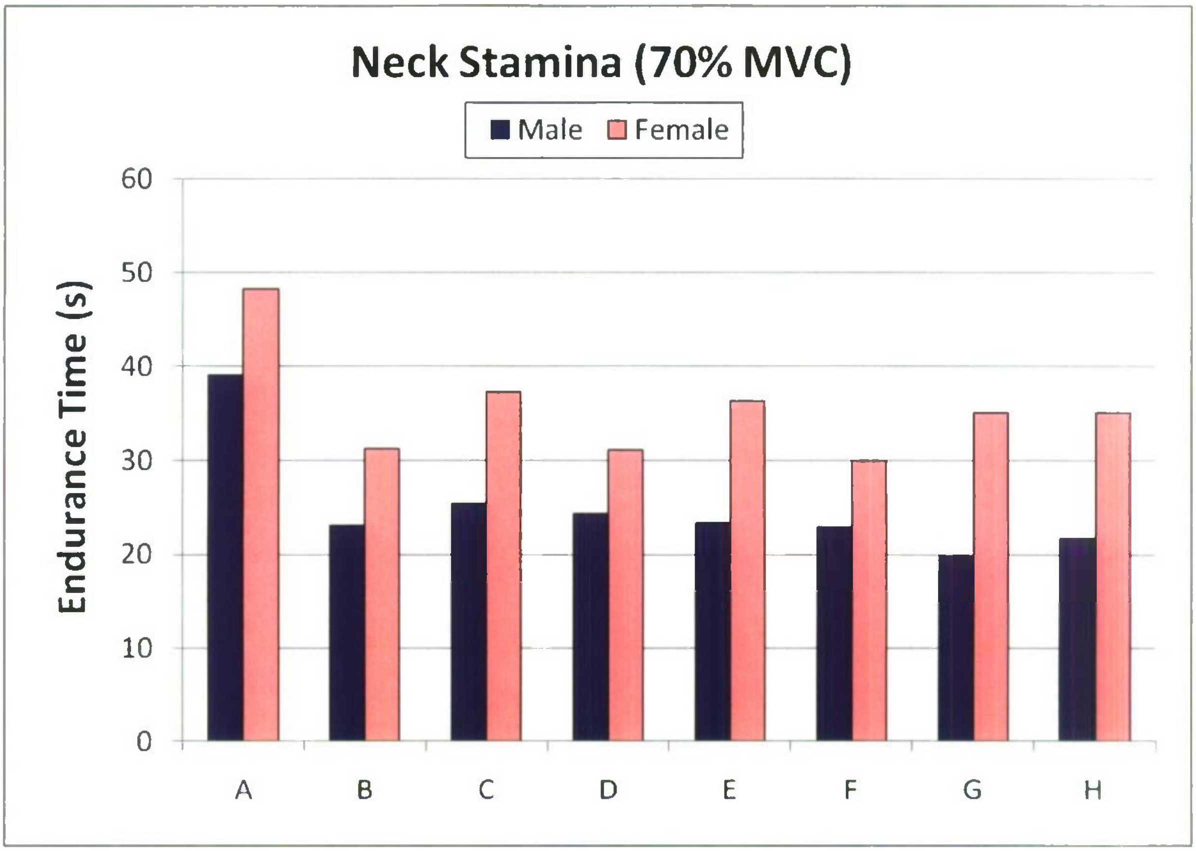

Figure 18. Male and Female Mean Endurance Times (seconds)

The data were then analyzed using a univariate and multivariate repeated measures approach. Examining the pre-test and post-test 100% MVCs, the univariate and multivariate repeated measures analysis agreed with respect to the significant Gender (p-value < 0.001) and Configuration (p-value < 0.001); however, the multivariate repeated measures analysis revealed a significant Configuration x Strength interaction term (p-value = 0.013) not observed in the univariate analysis. All of these factors were significant at the 0.05 level of significance within each analysis. As in the basic univariate analysis above, the male volunteers had significantly higher neck strength 100% MVC than the female volunteers (Figure 19).

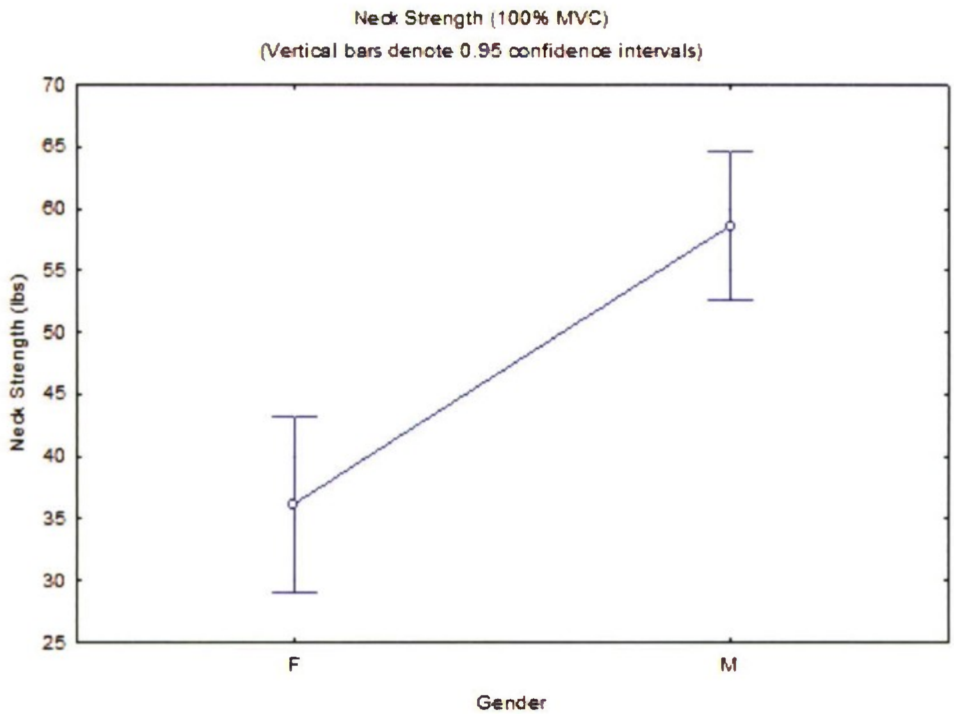

Figure 19. Neck Strength (100% MVC) by Gender

Figure 20 shows the pre-test configuration G, post-test configurations G, and post-test configuration A had the highest 100% MVC neck strength averages. The next highest neck strength averages were for pre-test configurations A and configuration H both pre- and post-test. However, for configurations A and G neither had a respirator. Using a Tukey multiple comparison adjustment, multiple statistically significant differences ($p \leq .05$) existed between the configurations which did not include the respirator (A and G) and those that did (B through F and H). The only observed differences ($p \leq .05$) between configurations with a helmet and respirator or respirator only were with configuration H. Configuration H had an average neck strength 100% MVC higher than for those configurations with a helmet and respirator (B, C, and D) or for those configurations with only a respirator (E and F). The only statistically significant differences ($p \leq .05$) for the 100% MVC using Tukey's adjustment for multiple comparisons were for H post-test versus C and E post-test.

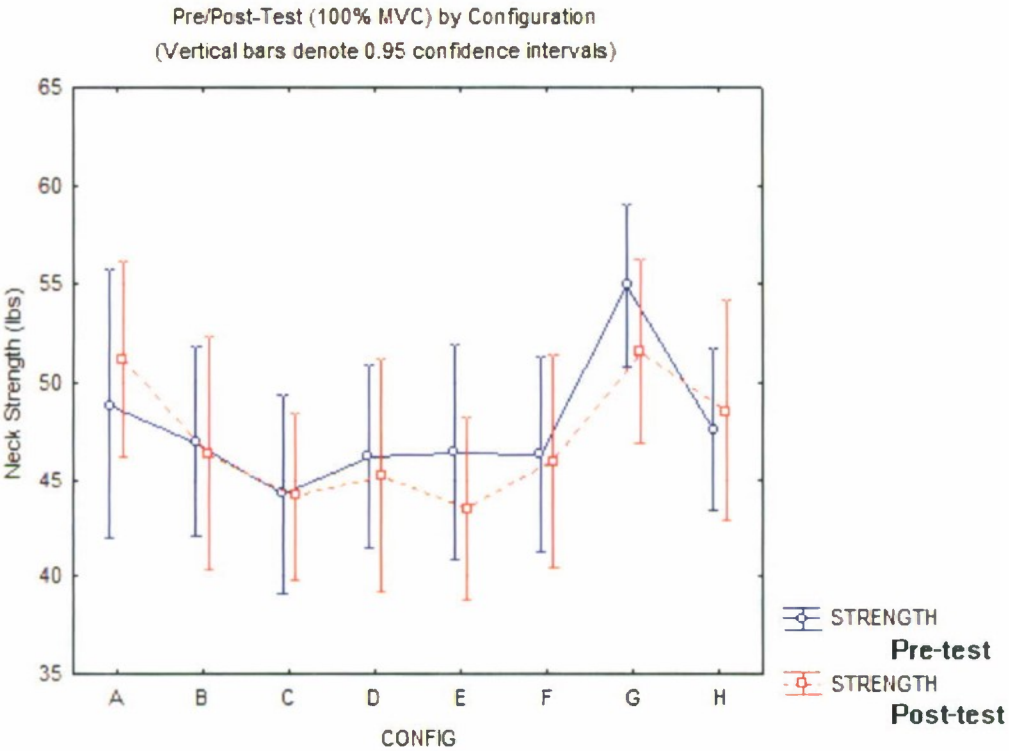

Figure 20. Neck Strength (100% MVC) by Pre/Post-Test x Configuration Interaction

In the analysis of the endurance data (70% MVC), the repeated measures analysis was consistent with the univariate analysis above. The female volunteers consistently lasted longer (on average) for their 70% MVC endurance runs vs. the male volunteers, although not statistically significant (*p*-value = 0.245). For the univariate repeated measures analysis, headgear configuration appeared to be the only significant factor. However, all the repeated measures factors failed the sphericity assumption including configuration. Once the model was adjusted using the Greenhouse-Geisser correction, no factors were significant at the 0.05 level. After this correction, headgear configuration was found to be border line significant with a *p*-value = 0.085. This was more than likely due to configuration "A" (Figure 21.). Using a multivariate repeated measures analysis, the only significant factor is "Hour" (*p*-value = 0.014) (Figure 22).

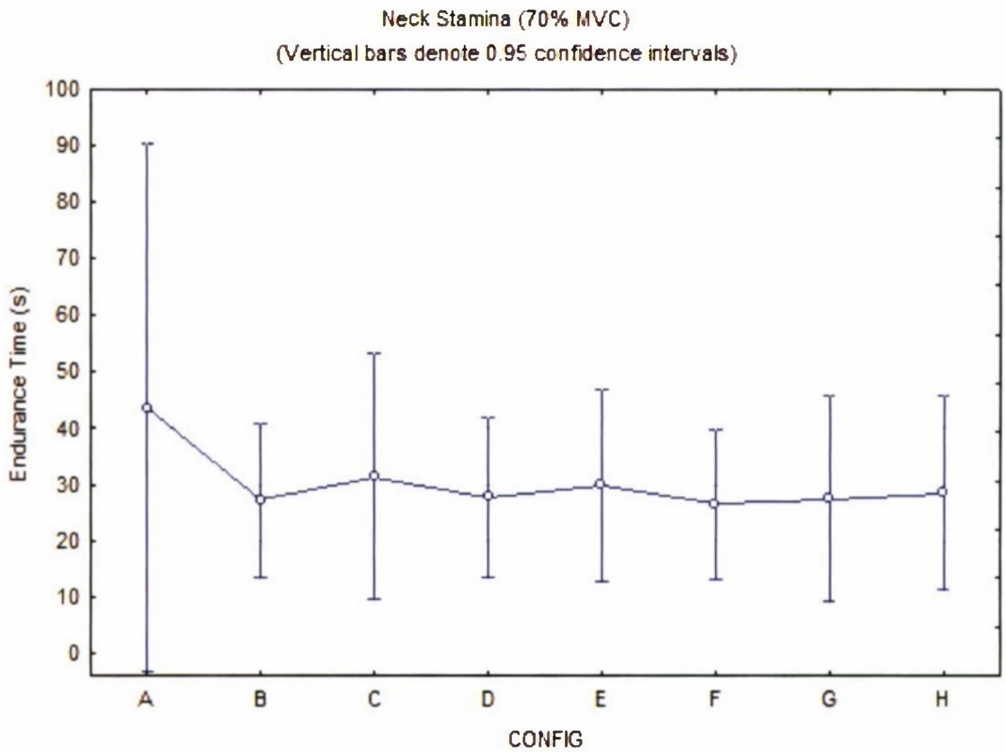

Figure 21. Neck Stamina Time (seconds) by Configuration

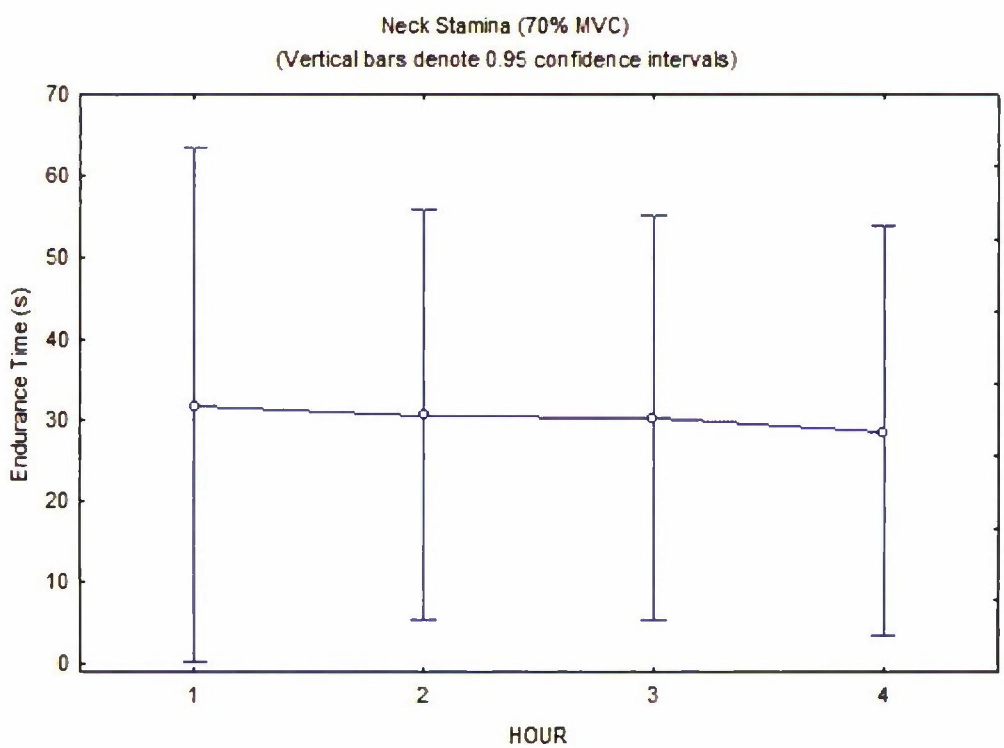

Figure 22. Neck Stamina Time (seconds) by Hour

In this case, the multivariate repeated measures analysis was used as the univariate analysis did not meet the sphericity assumption nor did the adjusted univariate analysis match or even follow the same general pattern of significance. As expected, there appears to be a slight decrease in endurance time with increasing hour (Figure 22). To determine which values of "Hour" differed for average endurance time, the Tukey multiple comparison adjustment was too conservative (no differences detected) so Fisher's multiple comparison adjustment was used instead. Based on the Fisher's multiple comparison adjustment, the only significant difference ($p \leq .05$) detected was from Hours "1" and "4".

3.3. Muscle Activity

As described earlier in this report, all EMG data were initially examined using the DelSys® EMG Works Analysis 3.5 Program and then converted to a .csv format for statistical analysis at Brooks City Base, San Antonio, TX. After the data were processed in Matlab, SPSS software was used to run descriptive, omnibus, and t-tests on relative data. Only the 70% data were fully assessed using SPSS. From this analysis at Brooks, no statistical differences were discovered between the left and right traps. The standard deviation (SD) was very high thus disqualifying the presumed difference. A full demonstration of the performed EMG data analysis is included in Appendix F.

In summary, the most relevant data in answering the question of fatigue come from the change in Hours "1" to "4". An increased RMS suggests more motor cells firing and thus a supposed increased force output. However, if the RMS increases and the output force decreases, or stays constant, fatigue can be attributed. Because the force exerted was kept relatively constant for the endurance runs by definition, the presence of fatigue was more prevalent at Hour "4" than Hour "1" based on the RMS data. Volunteers had to work harder to keep each endurance run going, and harder throughout the session (Hour "1" vs. Hours "2", "3", and "4"). As with RMS, frequency shift is most relevant over time. A positive shift suggests greater synchronization. With increased synchronization, greater output force would also be expected.

Limited statistical tests were performed to assess the affect of filter placement. The first test compared configurations B, C, D, and H. The second analysis compared configurations E and F. However, no significant correlations could be made. It is possible that correlations exist, only that the data set was too small to produce statistically relevant changes. The use of a respirator was assessed statistically as well. Nothing significant was observed for RMS, yet a positive frequency shift, meaning less fatigue was present for the configurations not using a respirator.

3.4. Perceived Discomfort:

The subjective comfort survey/questionnaire (Attachment 3) data looked at a variety of locations and at different aspects of comfort including 1) Fatigue and Weakness, 2) Pain and Aches, 3) Numbness or Loss of Sensation, 4) Hot Spots, 5) Perspiration and Sweat, and 6) Level of Difficulty/Exertion and Comfort. Results for all of these aspects of perceived discomfort are discussed herein.

3.4.1. Fatigue and Weakness: For questions related to the wearer's head, the results for the adjusted (Greenhouse-Geisser) univariate and the multivariate repeated measures ANOVA indicate the only statistically significant variables were configuration and time (Figure 23).

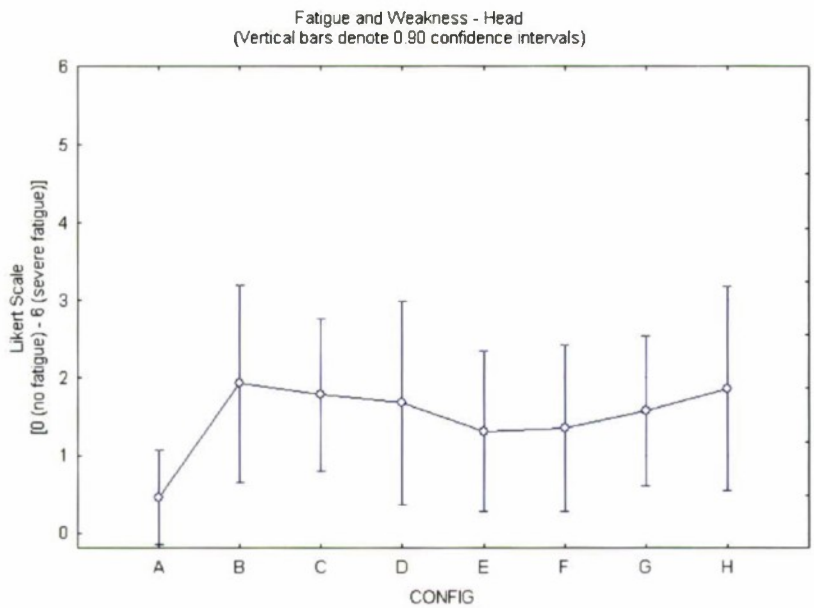

Figure 23. Fatigue and Weakness - Head by Configuration

Headgear configuration "A" (no headgear worn) is statistically different from configurations "B", "C", "D", "F", "G" and "H" at the 0.05 level and statistically different from configuration "E" at the 0.10 level (*p*-value = 0.054). In general, though, the scores were low with all the configuration averages below 2. With regards to time (Figure 24), all hours are different (at the 0.05 level) except for hours "3" and "4". Again, scores tended to remain low (hourly averages below 2), and as expected, volunteers reported more and more head fatigue and discomfort as the session went on.

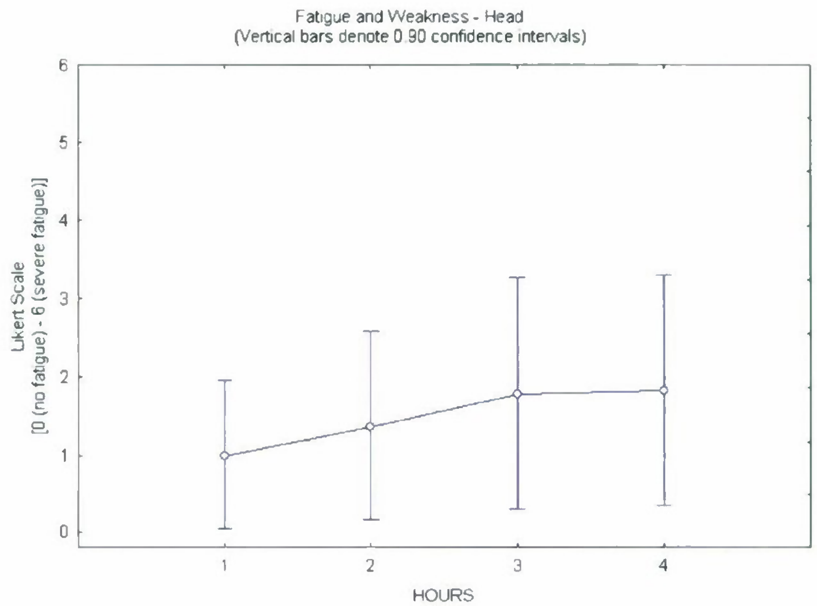

Figure 24. Fatigue and Weakness - Head by Hour

Similar results are seen for fatigue and weakness of the neck as with the head. Headgear configuration and time were the only significant variables (Figures 25 and 26). The adjusted (Greenhouse-Geisser) univariate and multivariate ANOVA were not identical this time. The adjusted univariate analysis included a significant variable at the 0.10 level time x gender interaction term (p-value = 0.055). In this case, it was decided to go with the multivariate ANOVA. The time x gender interaction plot is provided for completeness and for comparison (Figure 27).

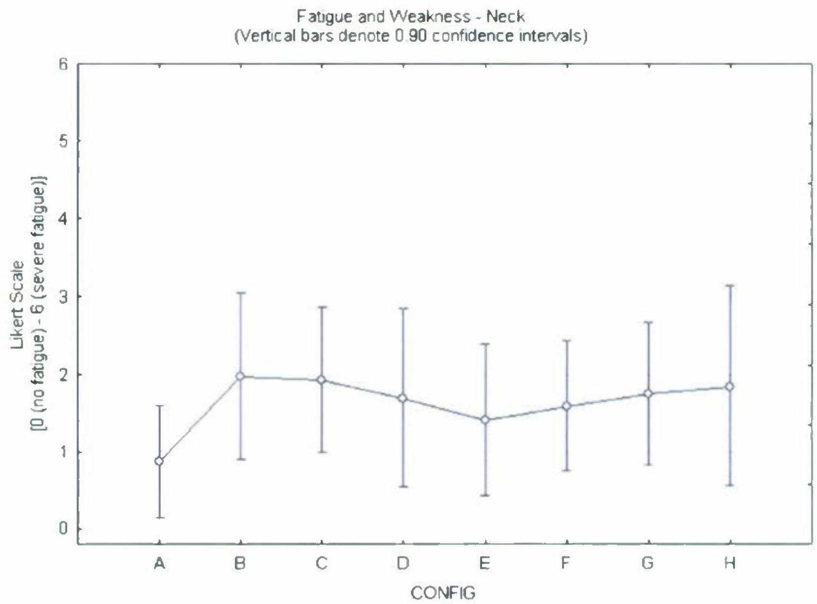

Figure 25. Fatigue and Weakness - Neck by Configuration

Headgear configuration "A" is statistically different from configurations "B", "C", "D", "G" and "H" at the 0.05 level and statistically different from configuration "F" at the 0.10 level (*p*-value = 0.093). There is no statistical difference between configurations "A" and "E". However, again, the scores were low with all the configuration averages below 2.

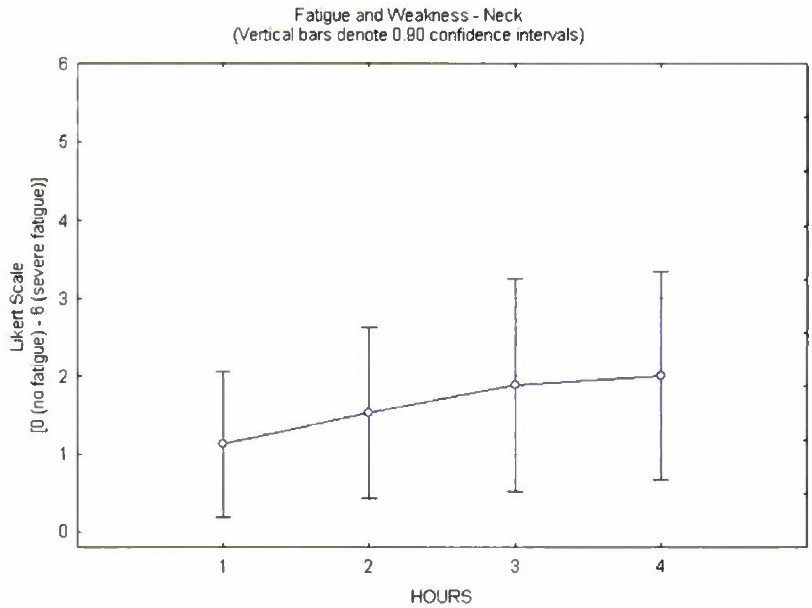

Figure 26. Fatigue and Weakness - Neck by Hour

With regards to time, all hours are different (at the 0.05 level) except for hours "3" and "4". Again, scores tended to remain low (hourly averages below 2).

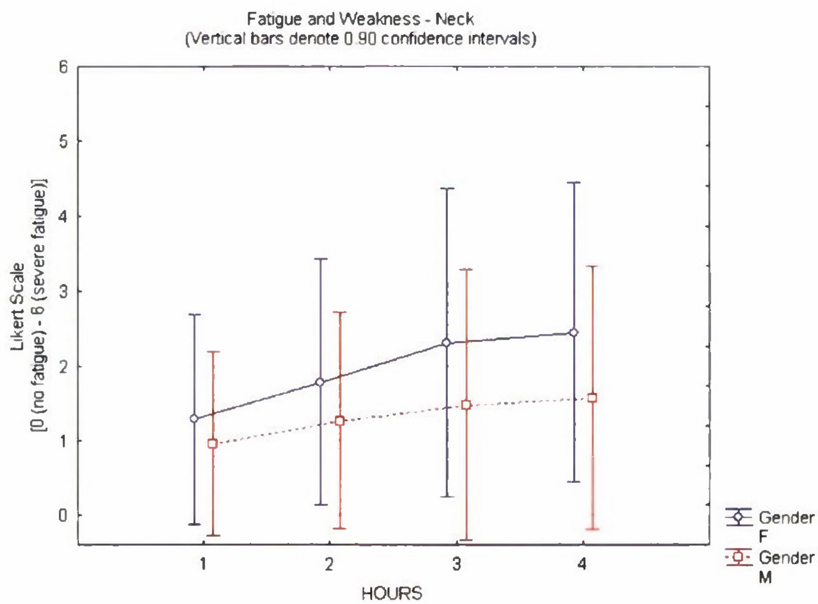

Figure 27. Fatigue and Weakness - Neck by Time x Gender Interaction

For the upper/middle back, the only variable significant is time at the 0.05 level (Figure 28).

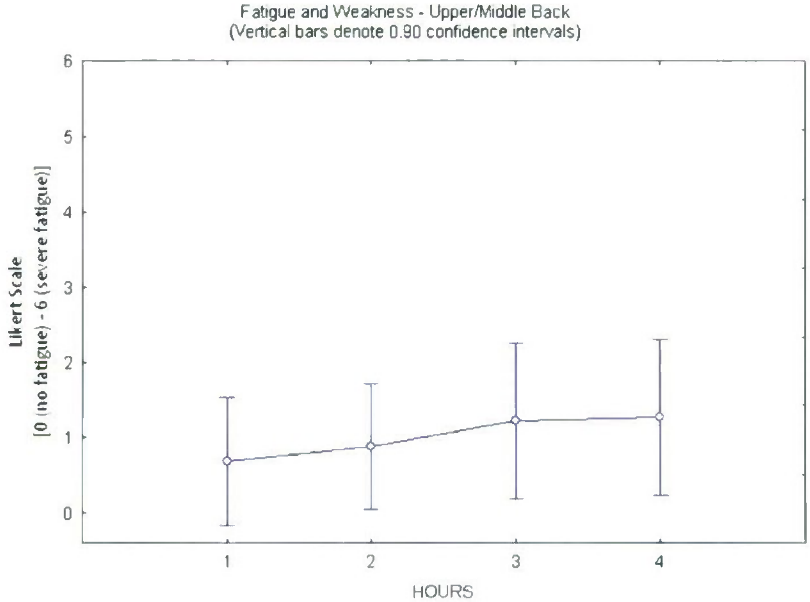

Figure 28. Fatigue and Weakness - Upper/Middle Back by Hour

With regards to time, Hours "1" and "2" are different (at the 0.05 level) from Hours "3" and "4". Again, scores tended to remain low (highest hourly averages just above 1).

For the lower back, there are significant time and gender effects via their interaction at the 0.10 level (*p*-value = 0.054) (Figure 29).

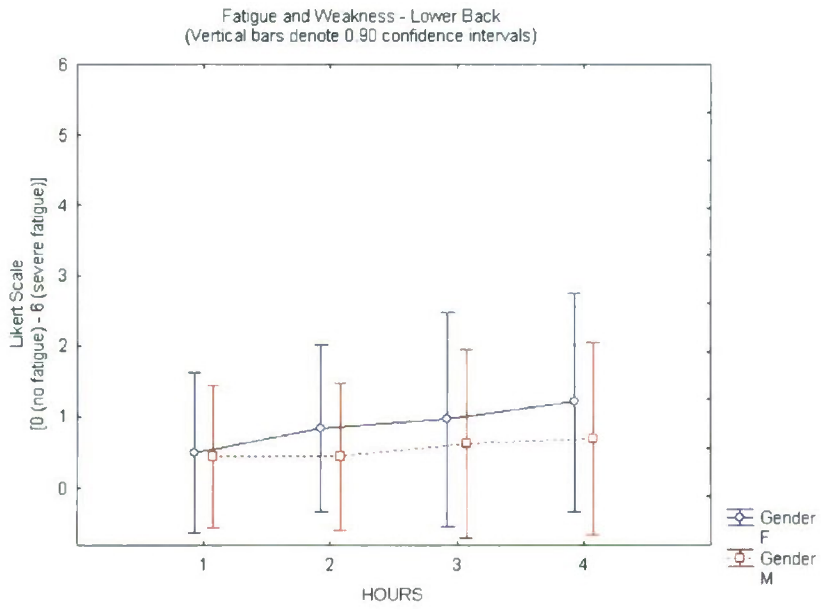

Figure 29. Fatigue and Weakness - Lower Back by Time x Gender Interaction

Examining the time x gender interaction, the differences are solely within the female gender. Hour "1" for the females is different than Hours "3" and "4" at the 0.05 level and different than Hour "2" at the 0.10 level. Additionally, Hour "2" is different from Hour "4" at the 0.05 level. There are no differences for the males.

3.4.2. Pain and Ache: For questions related to the wearer's head, the adjusted (Greenhouse-Geisser) univariate and multivariate repeated measures ANOVA (Figure 30) indicated that the only statistically significant variables were headgear configuration, time and gender with time and gender significant via their interaction (time x gender).

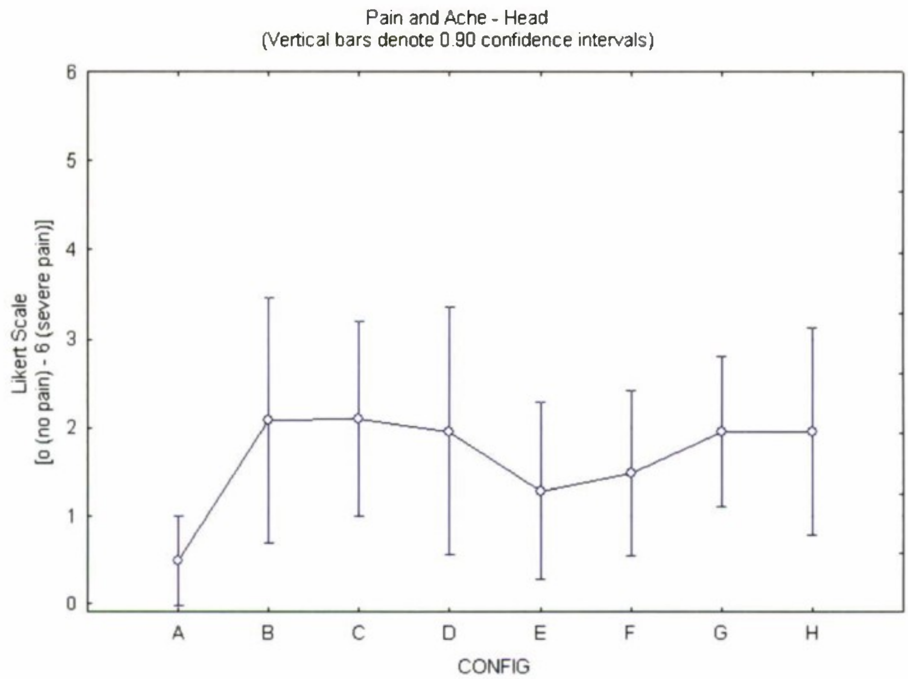

Figure 30. Pain and Ache - Head by Configuration

In this instance, headgear configuration "A" is statistically different at the 0.05 level from all other headgear configurations except for "E".

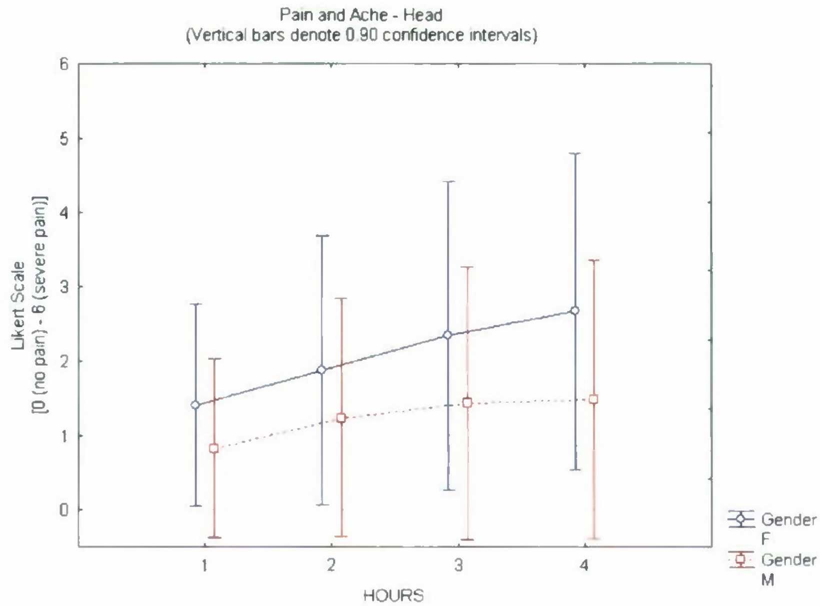

Figure 31. Pain and Ache - Head by Time x Gender Interaction

For the time x gender interaction term, the following differences (at the 0.05 level) are observed (Figure 31): Female at Hour "1" is statistically different from Female Hours "3" and "4"; Female Hour "2" is statistically different from Female Hour "4"; Male Hour "1" is statistically different from Female Hour "4" and Male Hours "3" and "4".

With regard to the neck related questions, the adjusted (Greenhouse-Geisser) univariate and multivariate ANOVA agreed. The only variables statistically significant are headgear configuration and time (Figure 32).

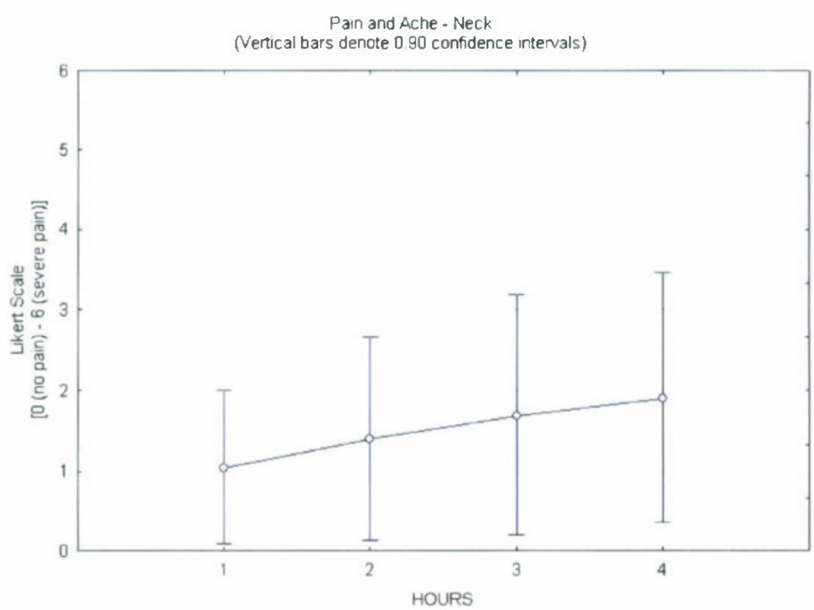

Figure 32. Pain and Ache - Neck by Hour

Similar to other time comparisons, Hour "1" is significantly different than Hours "2", "3" and "4" at the 0.05 level. Hour "2" is significantly different than Hour "3" at the 0.10 level and Hour "4" at the 0.05 level. Hours "3" and "4" are not statistically different from one another.

Again, the only differences center around headgear configuration "A", which is different from all the other configurations except "E" and "F" and only at the 0.10 level for "G" with all the others at the 0.05 level.

For the Upper/Middle Back, the only variable significant is time (at the 0.05 level) (Figure 33).

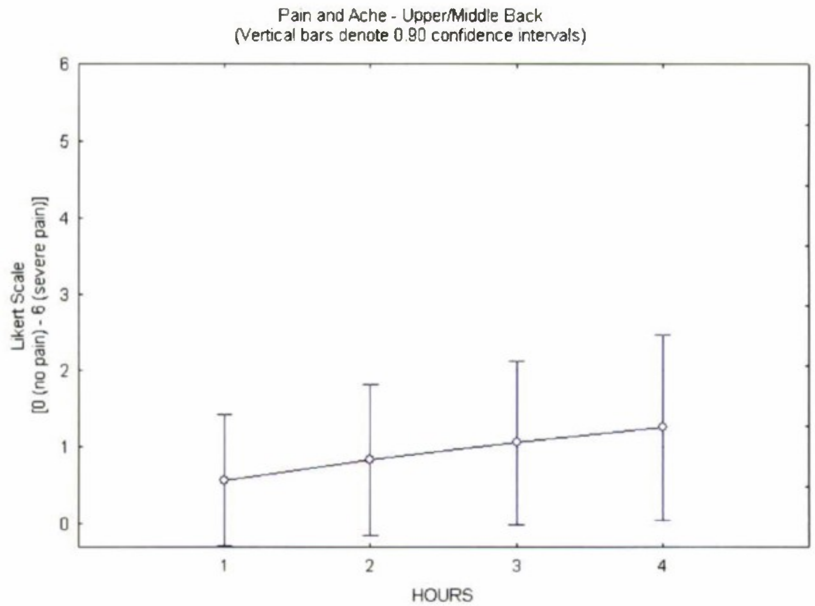

Figure 33. Pain and Ache - Upper/Middle Back by Hour

Hour "1" is significantly different from Hour "2" at the 0.10 level and Hours "3" and "4" at the 0.05 level. Hour "2" is also significantly different from Hour "4". Hours "2" and "3" are not significantly different and neither are Hours "3" and "4".

For the lower back, there is some difference between the adjusted univariate and multivariate ANOVA. The univariate ANOVA came up with a significant time x gender interaction term while the multivariate did not. The following paragraph focuses on the results of the multivariate ANOVA.

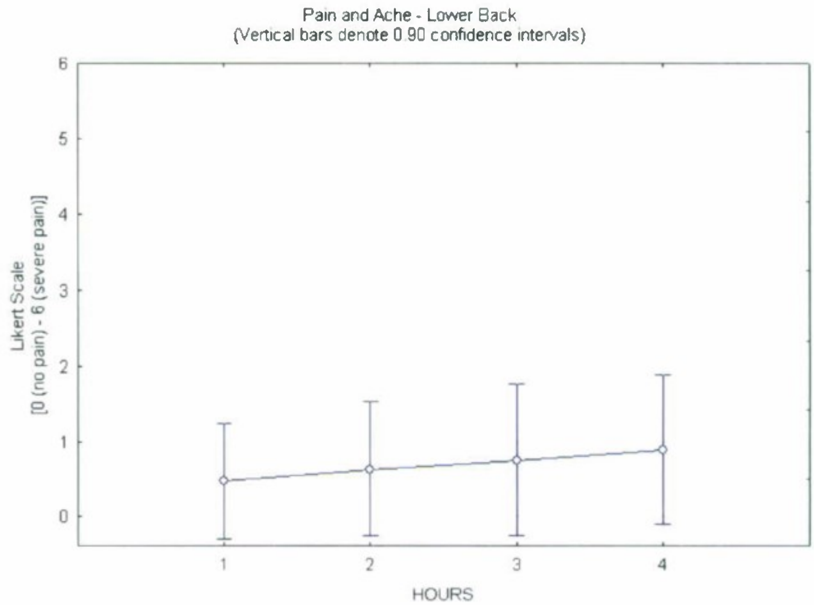

Figure 34. Pain and Ache - Lower Back by Hour

There are fewer differences in this instance (Figure 34). Hour "1" is statistically different from Hours "3" and "4". Hour "2" is statistically different from Hour "4". There are no differences between Hours "1" and "2", Hours "2" and "3", and Hours "3" and "4".

3.4.3. Numbness or Loss of Sensation: The head related questions here provided another instance where the adjusted univariate and multivariate repeated measures ANOVA did not agree. The results of the multivariate analysis are reported. The only variable significant for head is time (Figure 35).

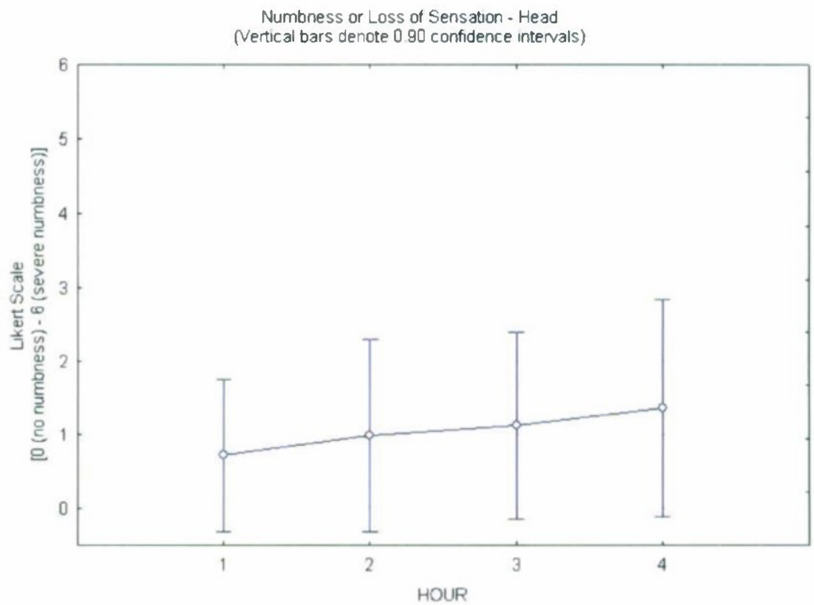

Figure 35. Numbness or Loss of Sensation - Head by Hour

Hour “1” is statistically different from Hours “2”, “3”, and “4” at the 0.05 significance level. Additionally, Hours “2” and “3” are both statistically different from Hour “4” at the 0.05 significance level.

For the neck, as with the head, the adjusted univariate and multivariate analyses did not agree. As before, the multivariate results are included. The multivariate analysis identified only time as the significant variable ([at the 0.05 level of significance] Figure 36).

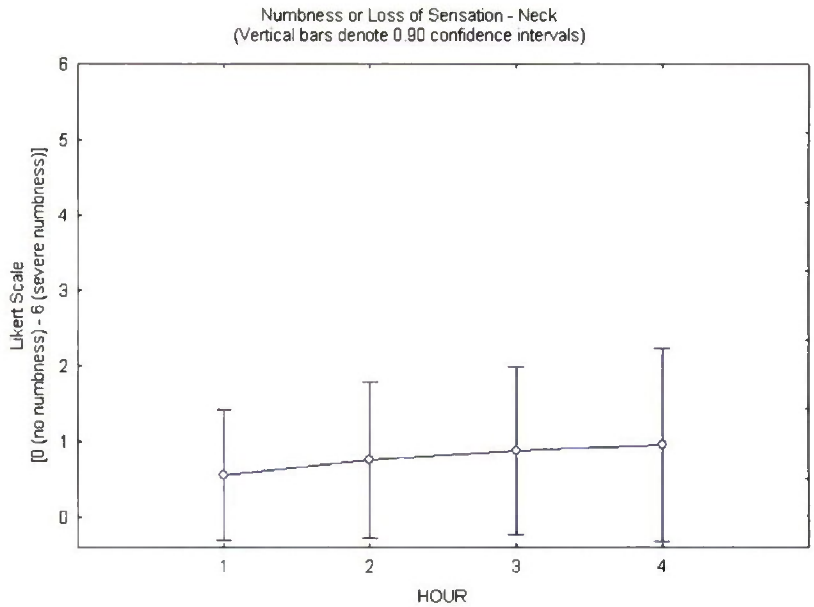

Figure 36. Numbness or Loss of Sensation - Neck by Hour

Hour “1” is statistically different from Hours “3” and “4” at the 0.05 level of significance.

The upper/middle back responses, consistent with previous body parts for numbness or loss of sensation, showed that the only significant variable was time (Figure 37).

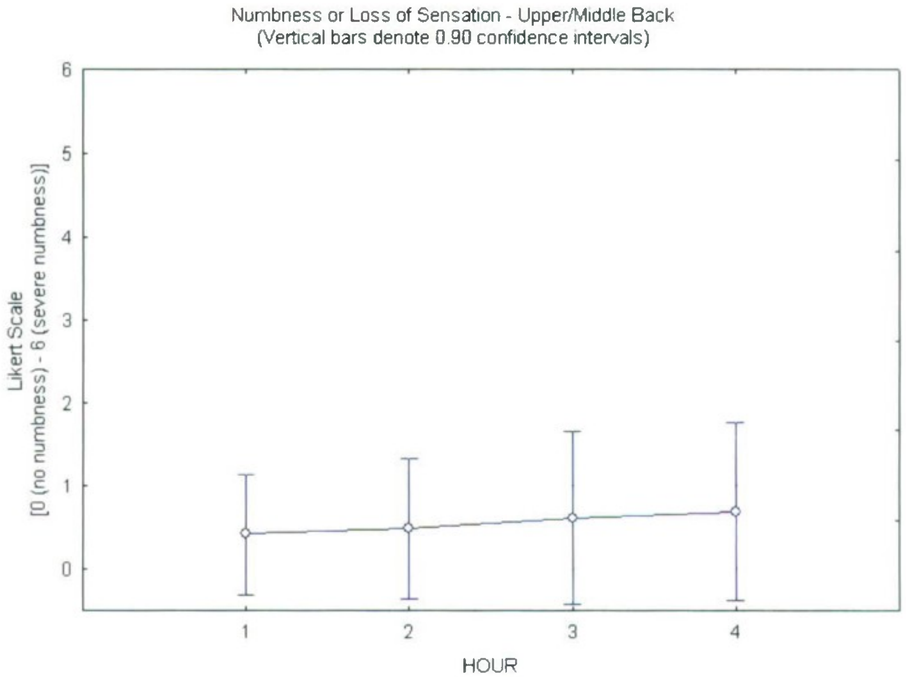

Figure 37. Numbness or Loss of Sensation - Upper/Middle Back by Hour

Hour "1" is statistically different from Hours "3" and "4" at the 0.05 level of significance. Hour "2" is statistically different from Hour "4" at the 0.05 level of significance.

For the lower back, the adjusted univariate repeated measures ANOVA resulted in a significant time variable at the $p = 0.05$ level; however, the multivariate ANOVA did not.

3.4.4. Hot Spots: Looking at the head related question results for the adjusted (Greenhouse-Geisser) univariate and multivariate repeated measures ANOVA, the only statistically significant variables were configuration and time.

As with the previous comparisons, the differences center mainly around headgear configuration "A", which is different from all the other configurations except "E" and only at the 0.10 level for "F" with all the others at the 0.05 level (Figure 38). Additionally, headgear configuration "E" is significantly different from configuration "B" at the 0.10 level.

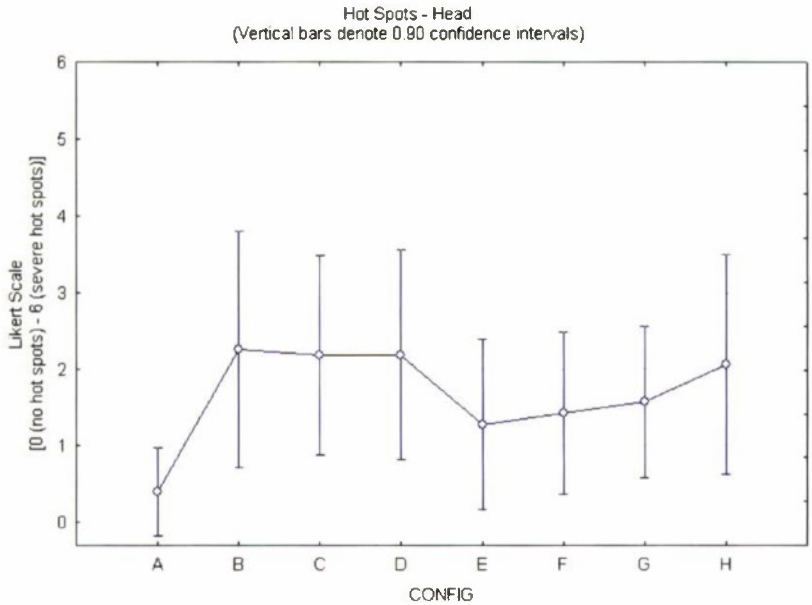

Figure 38. Hot Spots - Head by Configuration

Figure 39 shows Hour "1" is significantly different from Hours "3" and "4" at the 0.05 level and Hour "2" is significantly different from Hour "4" at the 0.05 level.

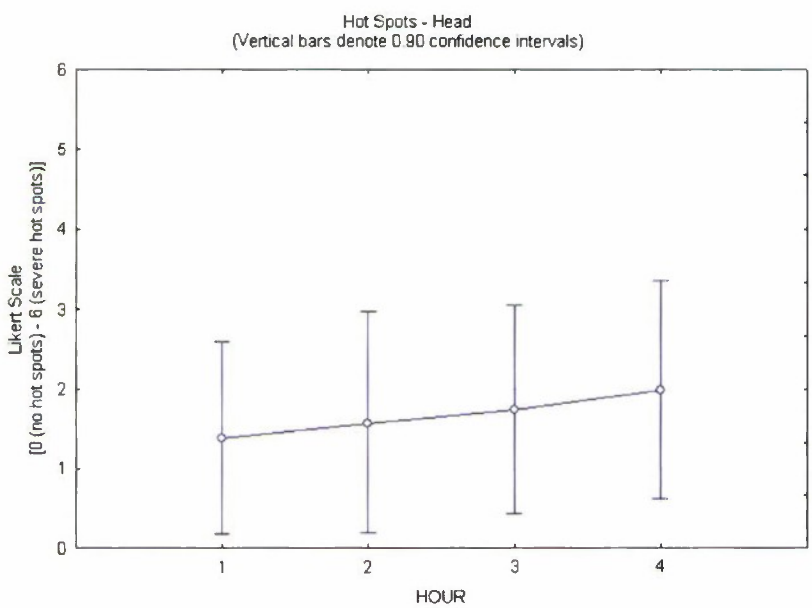

Figure 39. Hot Spots - Head by Hour

For the neck, there is a slight difference between the adjusted univariate and multivariate repeated measures ANOVA. The multivariate analysis had a significant time x gender variable along with headgear configuration and time. The multivariate results are reported.

Headgear configuration "A" is significantly different from configurations "B", "C", and "D" at the 0.05 level and from configuration "H" at the 0.10 level (Figure 40).

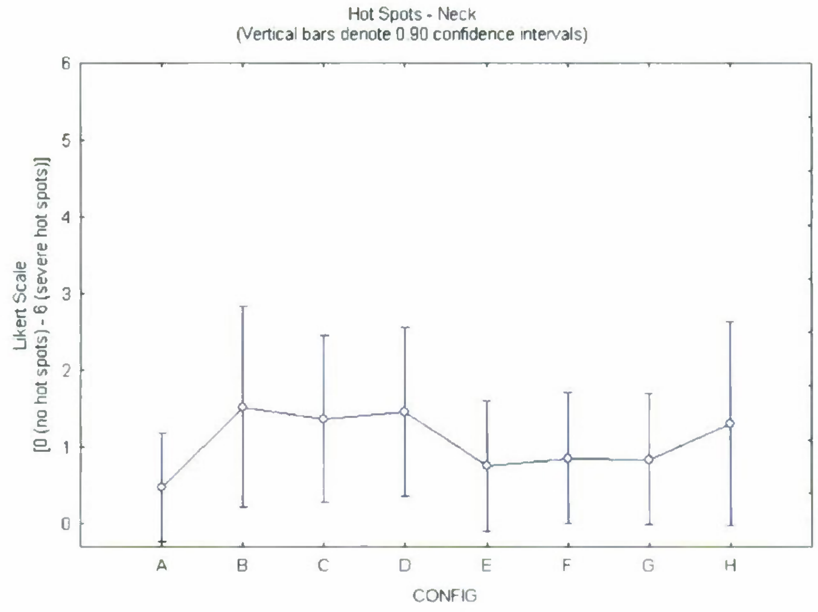

Figure 40. Hot Spots - Neck by Configuration

Figure 41 shows Female Hour "4" being significantly different from Female Hour "1" as well as Male Hour "4" being different from Male Hour "1" at the 0.05 significance level.

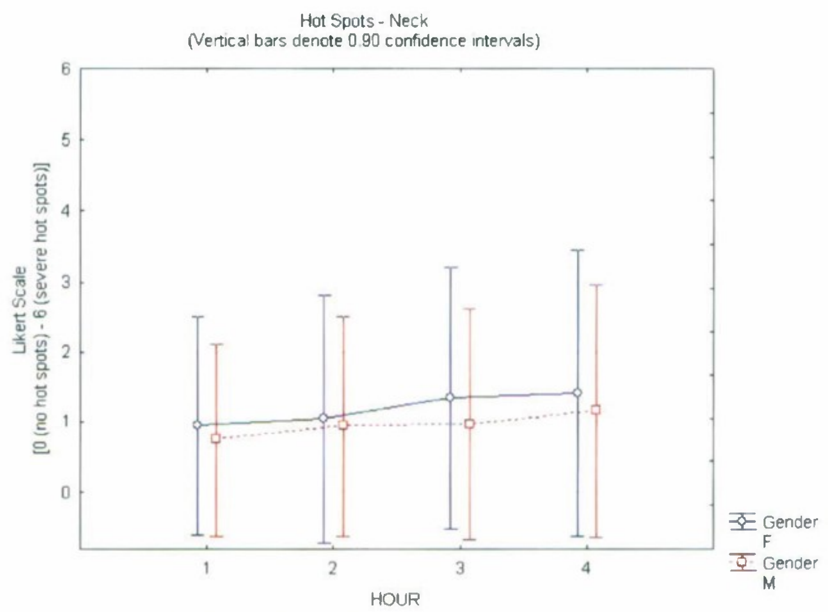

Figure 41. Hot Spots - Neck by Time x Gender Interaction

The adjusted univariate and the multivariate repeated measures ANOVA both agreed for the upper/middle back. The only variable significant for the upper/middle back is time (Figure 42).

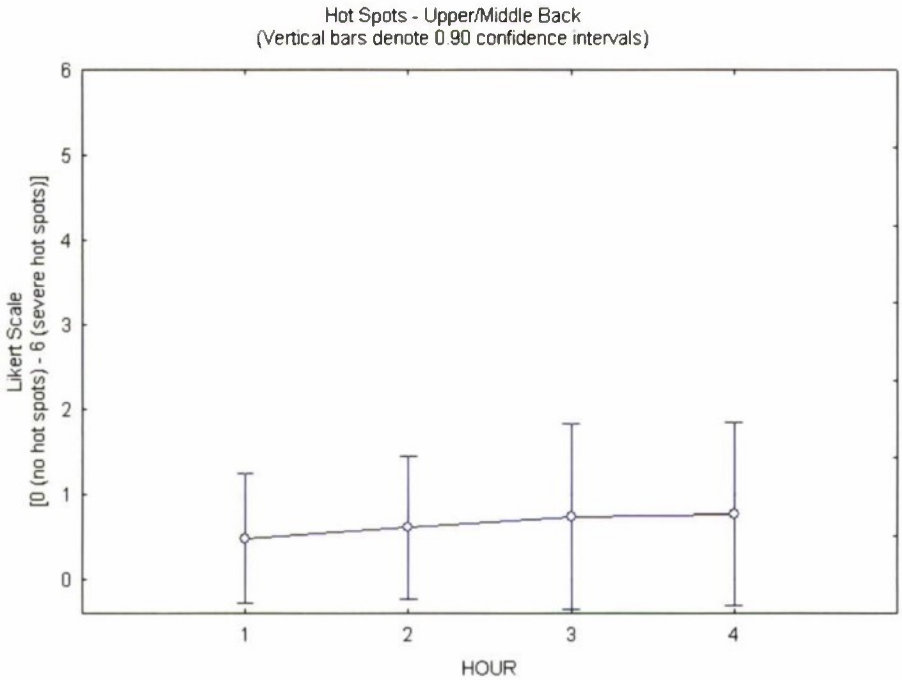

Figure 42. Hot Spots - Upper/Middle Back by Hour

Hour "1" is different from Hours "3" and "4" at the 0.05 level. No other differences were noted. Averages remained below 1 across all four hours.

3.4.5. Perspiration and Sweat: For the head related responses, the adjusted univariate and multivariate repeated measures ANOVA agreed. There is a significant headgear configuration, time, and time x gender interaction all significant at the 0.05 level. Headgear configuration "A" is statistically different from all other headgear configurations except "G". Headgear configuration "G" is statistically different from headgear configuration "B", "C", "D", and "H" (Figure 43).

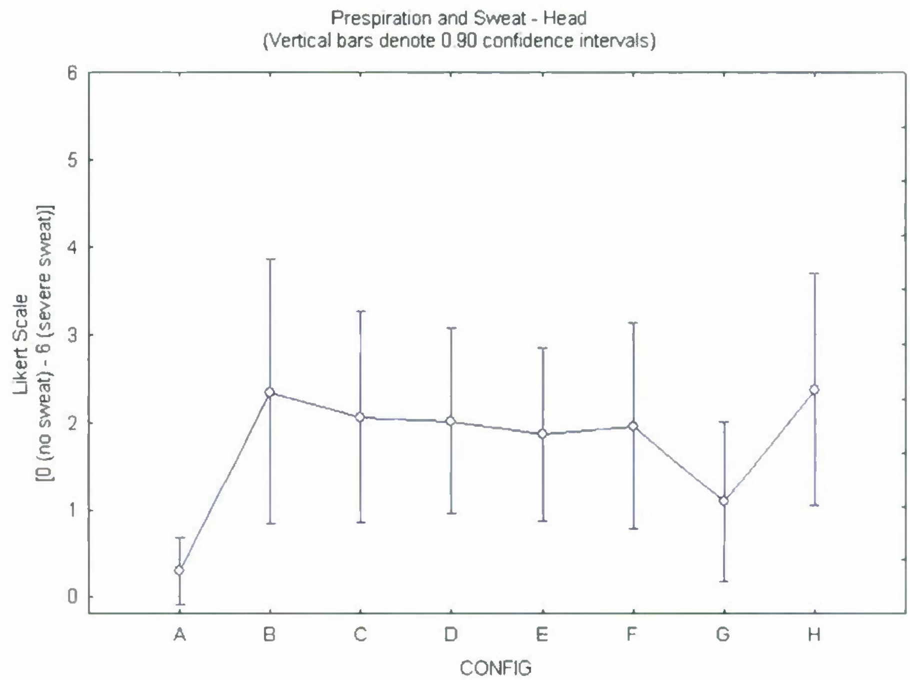

Figure 43. Perspiration and Sweat - Head by Configuration

Although there are no statistical differences for Female Hours "1" and "2" and for Female Hours "3" and "4", Female Hour "1"/"2" are statistically different from Female Hours 3"/" 4" at the 0.05 level of significance. The only statistically meaningful Male difference is between Hours "1" and "3" and between Hours "1" and "4" (Figure 44).

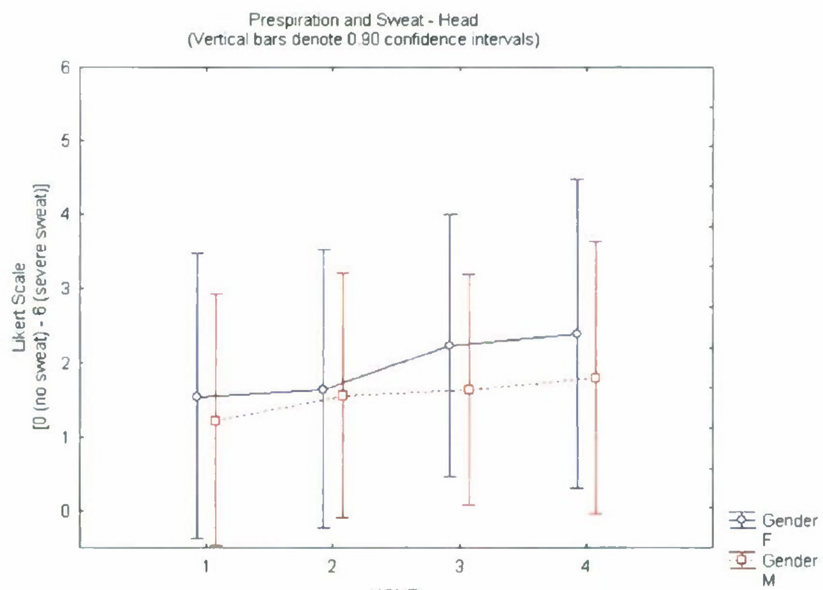

Figure 44. Perspiration and Sweat - Head by Time x Gender Interaction

For the neck, due to slight differences in the adjusted univariate and multivariate repeated measures ANOVA, the multivariate results are reported. For the neck data, only headgear configuration and time are significant.

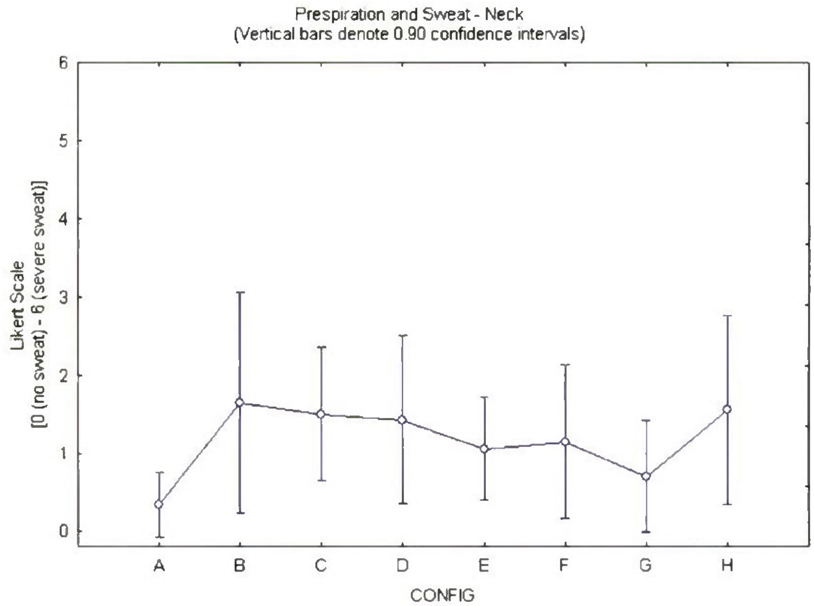

Figure 45. Perspiration and Sweat - Neck by Configuration

Headgear configuration "A" is statistically different from configurations "B", "C", "D", and "H" at the 0.05 level of significance. Headgear configuration "G" is statistically different from configuration "B" at the 0.05 significance level and "H" at the 0.10 significance level (Figure 45).

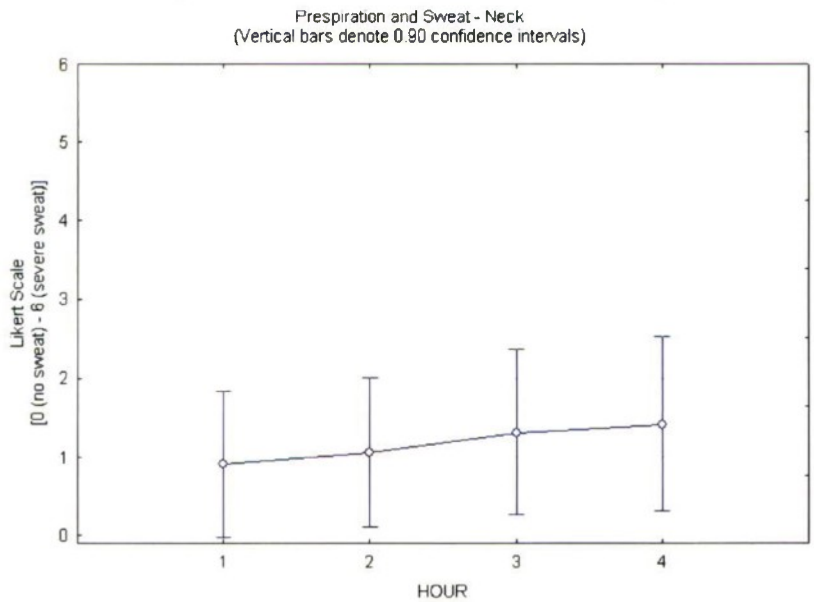

Figure 46. Perspiration and Sweat - Neck by Hour

For time, Hour "1" is statistically different from Hours "3" and "4" at the 0.05 level of significance. Hour "2" is statistically different from Hour "4" at the 0.05 level of significance and Hour "3" at the 0.10 level of significance (Figure 46).

Results for the upper/middle back are consistent with previous analyses; the only significant variables are headgear configuration and time. Both the adjusted univariate and multivariate repeated measures ANOVA agreed in this case.

Headgear configuration "A" is statistically different from configurations "B", "C", "D", and "H" at the 0.05 level of significance. No other differences were detected (Figure 47).

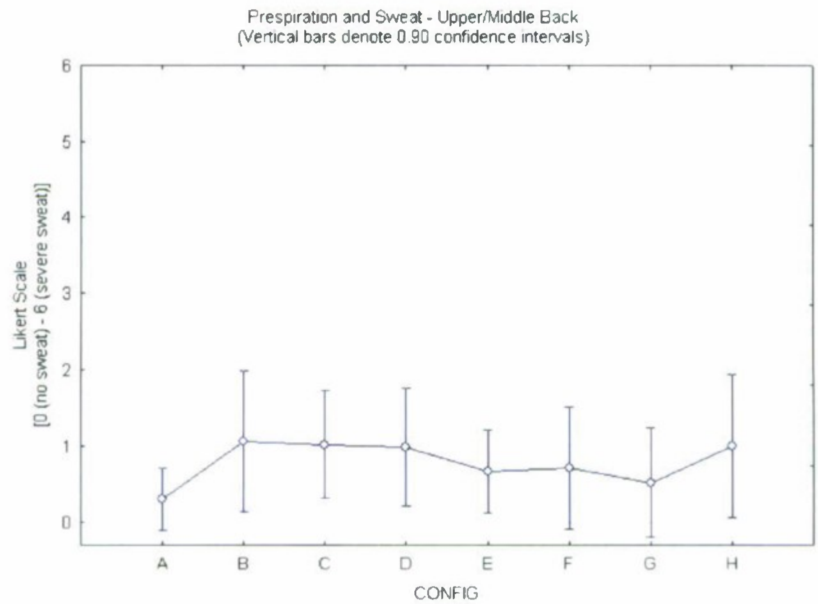

Figure 47. Perspiration and Sweat - Upper/Middle Back by Configuration

For time (Figure 48), Hour "1" is statistically different from Hours "3" and "4" at the 0.05 level of significance. Hour "2" is statistically different from Hour "4" at the 0.10 level of significance.

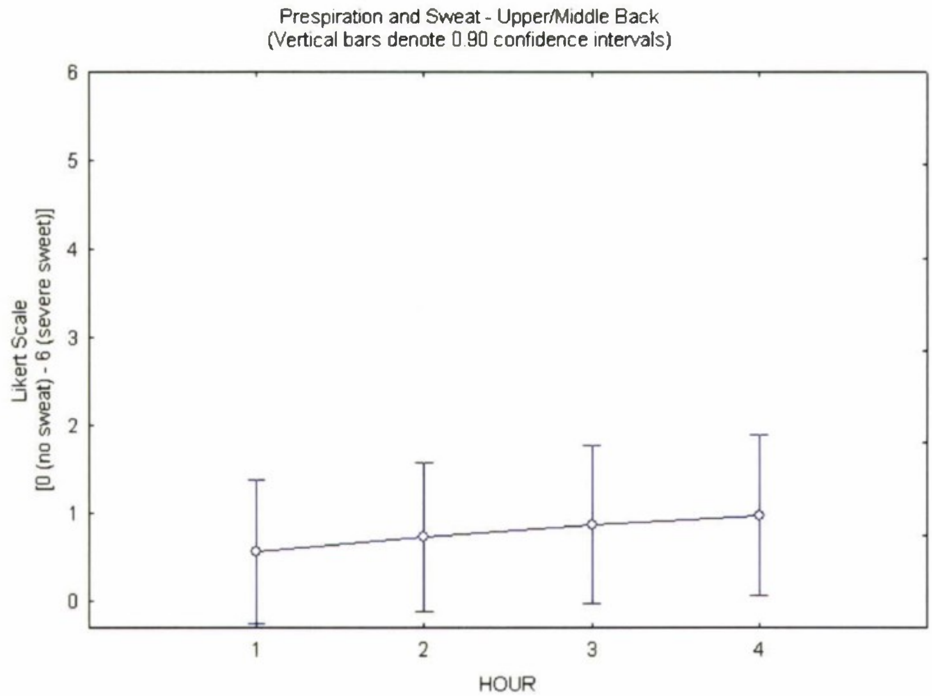

Figure 48. Perspiration and Sweat - Upper/Middle Back by Hour

3.4.6. Level of Difficulty, Exertion, and Comfort: The only significant variables related to the level of difficulty keeping the head/chin up are headgear configuration and time. The adjusted univariate and multivariate repeated measure ANOVA agreed in this case. Although headgear configuration is significant, the only difference (p-value ≤ 0.05) was configuration "A" with all other configurations. There were no significant differences among the other headgear configurations (Figure 49).

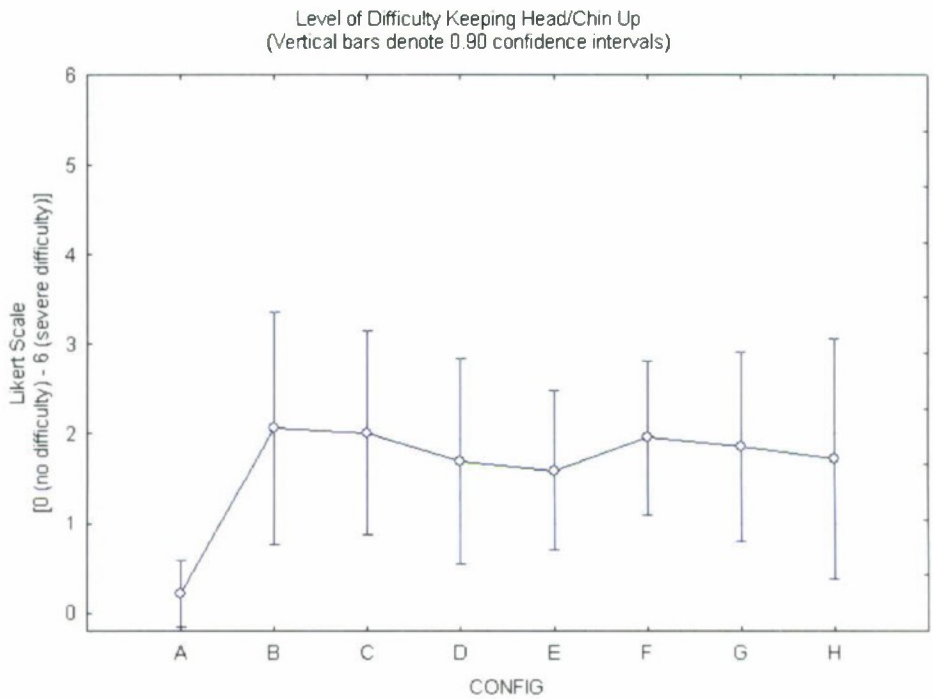

Figure 49. Level of Difficulty Keeping Head/Chin Up by Configuration

As expected with the level of difficulty over time, the average score increased with time. In this instance, Hour "1" is statistically different from Hour "2" at the 0.10 level and statistically different from Hours "3" and "4" at the 0.05 level. The only other difference to note is Hour "2" with Hour "4" also at the 0.05 level (Figure 50).

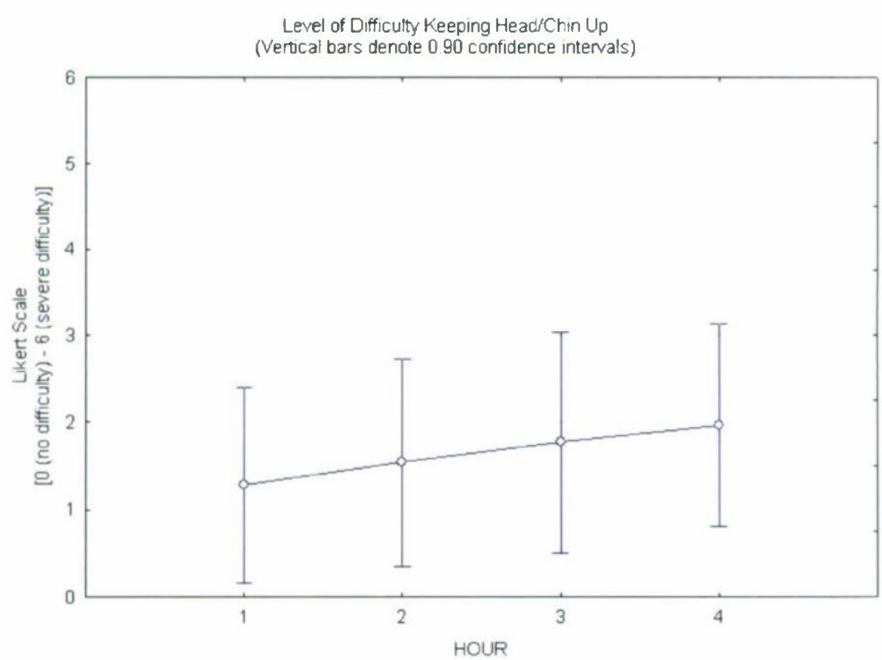

Figure 50. Level of Difficulty Keeping Head/Chin Up by Hour

The scale used to assess the volunteer's perceived level of exertion is reversed compared to previous scales. Headgear configuration and time were the only significant variables. The adjusted univariate and multivariate repeated measures ANOVA agreed in this instance. Headgear configuration "A" was significantly different from all the other headgear configurations (at the 0.10 level for headgear configuration "F" and at the 0.05 level for all others) (Figure 51).

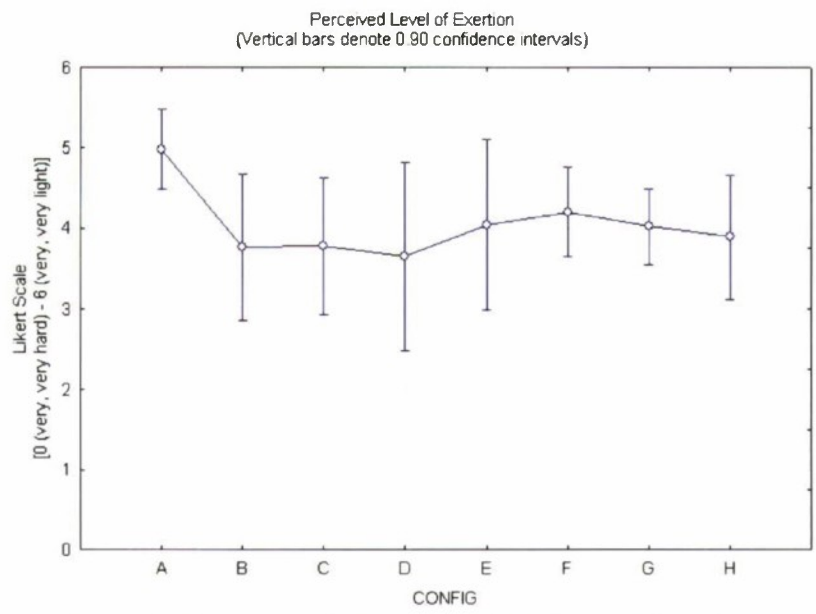

Figure 51. Perceived Level of Exertion by Configuration

Similarly to the level of difficulty measure, Hour "1" for perceived level of exertion was significantly different from Hour "2" at the 0.10 level and from Hours "3" and "4" at the 0.05 level of significance. Hour "2" was also significantly different from Hour "4" at the 0.05 level of significance (Figure 52).

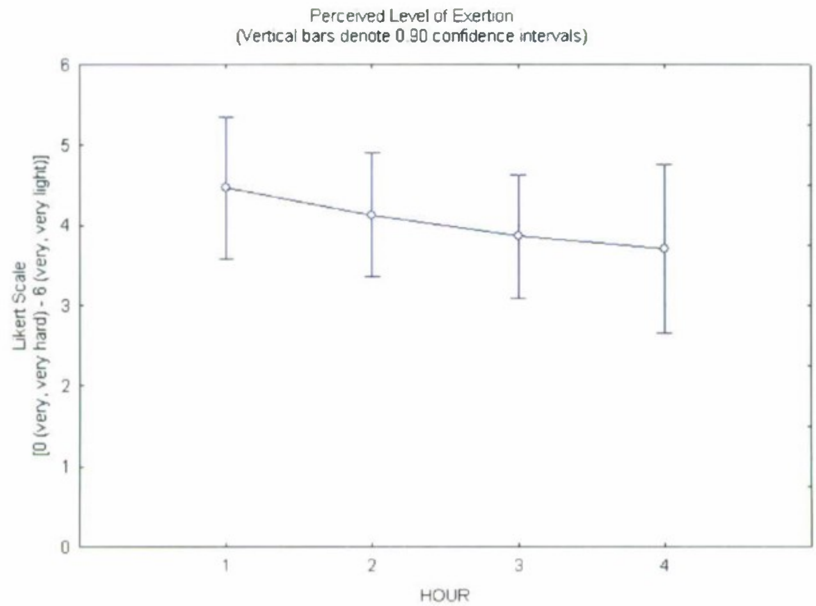

Figure 52. Perceived Level of Exertion by Hour

Like perceived level of exertion, the comfort scale used for this question is reversed as compared to the rest of the questionnaire. With regards to respirator/helmet combination comfort, there appears to be a more complex relationship than in the previous two analyses (level of difficulty and level of exertion). However, although one interaction (specifically headgear configuration x time) appears to be statistically significant (adjusted univariate), it is unlikely to be of practical significance. Additionally, the multivariate analysis did not have enough degrees of freedom to test this interaction term. The interpretation of this interaction also becomes complicated with the headgear configuration x time term in the model. Graphs of both the headgear configuration x time and the individual variables are provided below for comparison (Figure 53).

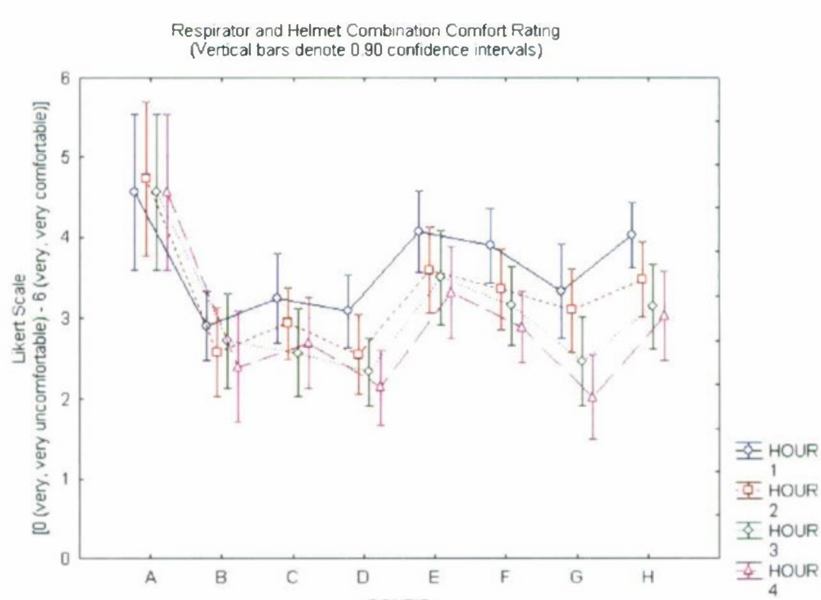

Figure 53. Respirator and Helmet Combination Comfort Rating by Configuration x Time

In this instance, the only statistical differences are configuration "A" with configurations "B", "C", "D", "F", and "G" at the 0.05 significance level and with configuration "H" at the 0.10 significance level. There were no statistically significant differences among configurations "B" through "H" (Figure 54).

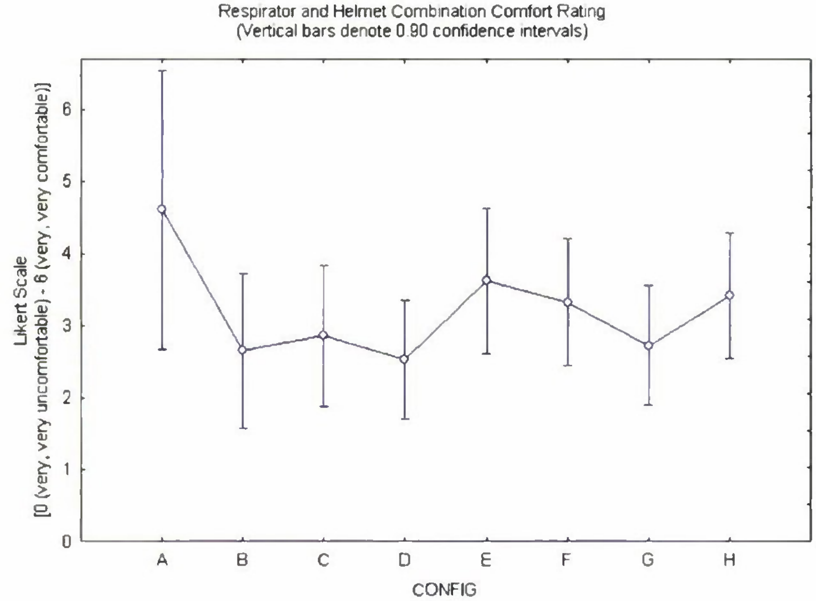

Figure 54. Respirator and Helmet Combination Comfort Rating by Configuration

For time, Hour "1" is statistically different from the other three hour periods (at the 0.05 level of significance). Hour "2" is also statistically different from Hour "3" at the 0.10 significance level and from Hour "4" at the 0.05 significance level (Figure 55).

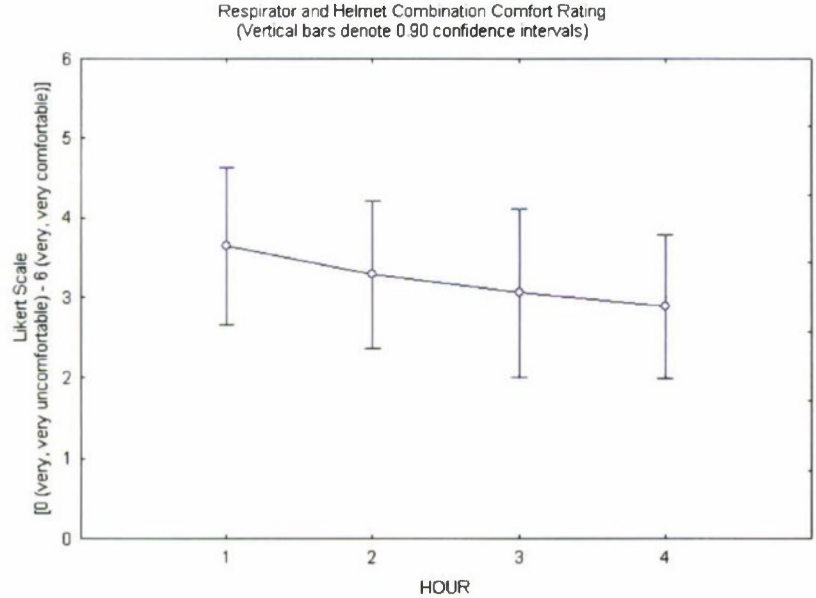

Figure 55. Respirator and Helmet Combination Comfort Rating by Hour

The headgear configuration x gender interaction term, even though statistically significant in the multivariate analysis at the 0.05 level of significance, it is unlikely of practical significance. Looking beyond configuration "A", it appears the "Females" are rating the comfort level lower than the "Males". Not much of a pattern difference exists between genders (Figure 56).

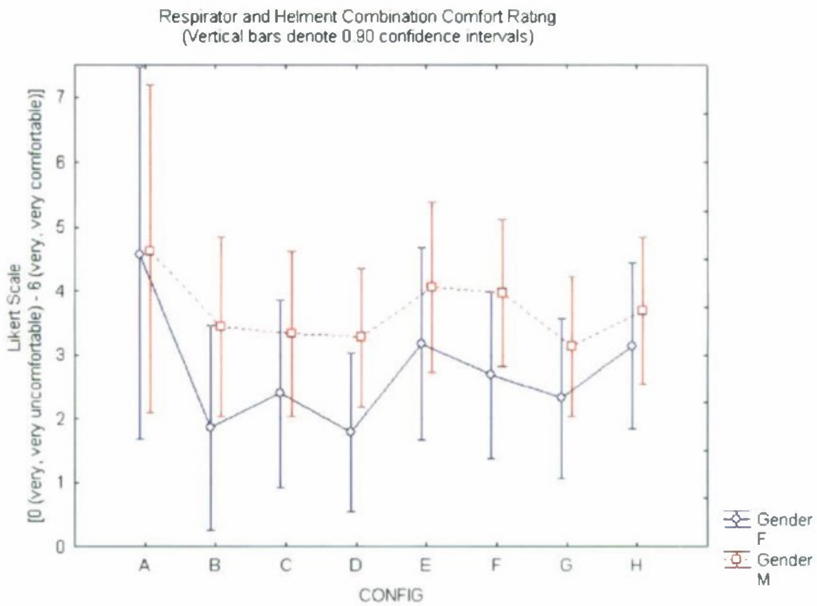

Figure 56. Respirator and Helmet Combination Comfort Rating by Configuration x Gender

Considering these survey/questionnaire data (Figure 57), a recommendation could be made that only the main affects of headgear configuration, time, and gender should be examined to explain the significance of respirator and helmet configuration comfort.

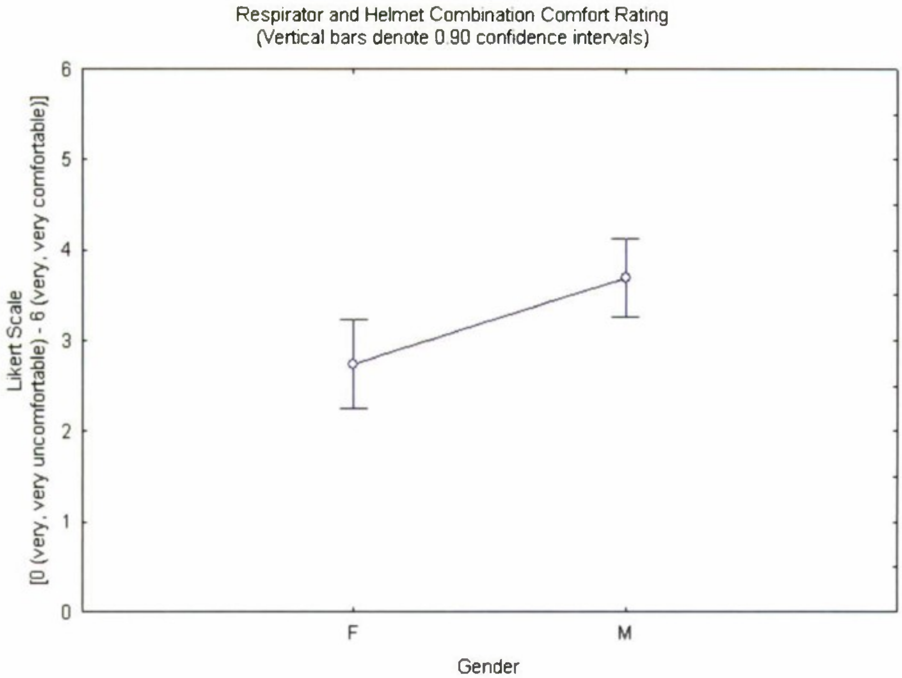

Figure 57. Respirator and Helmet Combination Comfort Rating by Gender

4. DISCUSSION AND CONCLUSIONS

The mass properties of the seven head gear configurations were measured to determine the center of gravity (CG) shift when the gear was worn. In terms of worse case or best case mass properties, configuration "G" (helmet only with rear filter) resulted in the greatest CG shift rearward and upward, and configuration "F" (respirator only with front filter) resulted in the greatest CG shift forward and downward. These two configurations caused the most torque on the head and neck and likely the most discomfort. However, these configurations did not include all possible headgear (i.e., helmet, respirator, and filter). Of these configurations, configuration "D" (helmet and respirator with rear filter) resulted in the greatest CG shift rearward and upward. Configuration "C" (helmet and respirator with front filter) resulted in the greatest CG shift forward. The configurations resulting in the least amount of CG shift and including all the headgear were "H" (helmet and respirator with left arm filter) and "B" (helmet and respirator with left side filter) These two configurations would induce the least amount of torque on the head and neck and likely cause the least discomfort.

The neck strength device provided a method to measure volunteers' neck strength and endurance. As expected, the males had significantly greater neck strength than the females. Somewhat surprisingly, although not statistically significant, the female volunteers had longer average endurance times than the male volunteers for all configurations. This may be an indication that the male volunteers gave a truer 100% Maximum Voluntary Contraction (MVC) at the beginning of the session. There was a high correlation found between neck strength and neck circumference at the mid-cervical spine for both pre- and post-test MVCs, and a moderate correlation found between neck strength and weight for both pre- and post-test MVCs.

For the 100% MVC, configurations "A" (no helmet or respirator) and "G" (helmet only with rear filter) had the highest average neck strength; although, neither of these configurations contained all the headgear. Regarding configurations with a respirator, configuration "H" (helmet and respirator with left arm filter) resulted in the highest average neck strength although there was no evidence of any statistical difference between the other respirator configurations ("B"–"F") when compared to the "H" configuration. The strength results indicate that for the configurations including all the gear, configuration "H" resulted in the strongest pulls.

With regards to the 70% MVC stamina data, the only statistically significant factor was "Hour". As "Hour" increased, the endurance time (seconds) decreased. With regards to configurations, configuration "A" had the longest endurance time although not statistically different from the other configurations. No configuration can be recommended based on the endurance results.

Electromyography EMG was collected from the left and right pairs of the upper trapezius muscle at the level of the splenius capitus. The most notable results concern the increase in fatigue from Hour "1" to "4". An increased Root Mean Square (RMS) at Hour "4" vs. Hour "1" suggests more motor cells firing and thus a supposed increased force output. As the force exerted during the endurance runs had to be kept relatively constant (70% +/- 2 lbs.), and volunteers had to work harder to keep each endurance run sustained, and harder throughout the session (Hour "1" vs. Hours "2", "3", and "4"), increases in RMS from Hour "1" to "4" may be attributed to neck muscle fatigue. As with RMS, frequency shift is most relevant over time. A positive shift suggests greater synchronization. With increased synchronization, greater output force would also be expected. While two different statistical tests were run looking at filter placement, (B, C, D, & H, versus E & F), no significant correlations could be made. It is possible that correlations exist, only that the data set was too small to produce statistically relevant changes. Regarding the use of a respirator, nothing significant was observed for RMS, yet a positive frequency shift (less fatigue) was present for the configurations not using a respirator. No configuration can be recommended based on the EMG results; however, additional data need to be analyzed.

To determine whether a correlation existed between head gear configurations and perceived discomfort, volunteers completed a computerized comfort survey/questionnaire near the end of every hour throughout the four hour session, as well as pre- and post-sessions. In general, the main difference in headgear configurations occurred with configuration "A" (no helmet or respirator). If this configuration were removed, there would be very few differences among the remaining headgear configurations. With regards to time, the longer the volunteers wore the gear the more the volunteers reported fatigue/weakness, pain/aches, numbness, hot spots, etc.

If evaluating the subjective data discounting configuration "A", the next most favorably rated choice would be configuration "E" (respirator only with left side filter). When comparing configurations with only a respirator, the preferred location of the filter was found to the side (left side mounted). There were two exceptions, the first being "Numbness or Loss of Sensation" in which the only significant variable was "Time" and the second was for "Perspiration and Sweat" in which configuration "G" (helmet only with rear filter) performed best, after "A", which is not surprising because there was no respirator worn with this configuration. Regarding the configurations that included both the helmet and respirator, there were no statistical differences noted between any of these configurations. However, for the "Level of Difficulty Keeping Head/Chin up" measure, configurations "D" (helmet and respirator with rear filter) and "H" (helmet and respirator with left arm filter) had a lower average score (i.e., less difficulty) than the other configurations with both a helmet and respirator. Similarly, configuration "H" scored better in the “Respirator and Helmet Combination” comfort rating. In both instances, however, the differences were not significant at the 0.10 level. The comfort survey/questionnaire results indicate for configurations including all the headgear that configurations “B” (helmet and respirator with left side filter) and “H” (helmet and respirator with left arm filter) were the most comfortable.

All volunteers were able to perform the common law enforcement representative tasks with little or no problem. During these tasks, the volunteers complained the most about configuration “G” (helmet only with rear filter). They complained about the helmet wanting to slip rearward causing the chinstrap to become uncomfortable as it imbedded into their neck/chin area. This slippage was due to the extreme rearward and upward CG of the helmet. The same complaints were voiced about configuration “D” (helmet and respirator with rear filter), but not nearly as frequently. Using a more current ballistic helmet with interior padding and a tighter fit (e.g., the Advanced Combat Helmet) may have resolved this issue. Most other complaints were regarding the respirator being hot, sweaty, and difficulty in breathing normally. Given that the respirators were worn without additional Chemical, Biological, Radiological, and Nuclear personal protective equipment (PPE) clothing and were modified to minimize inhalation resistance, it is likely that these comments were precipitated by the volunteers’ lack of experience wearing respirators and ballistic helmets.

Generally, and not surprisingly, headgear configurations that reduced the weight on the head (e.g., removed the filter, helmet, or respirator from the head) were perceived more favorably than those that carried all PPE subsystems on the head concurrently. Also, in general, the headgear configurations that resulted in the smallest shifts in CG were viewed most favorably. Within the parameters of this study, very little future PPE design guidance can be gleaned from the neck strength, stamina, or EMG data. The headgear variables assessed did not prevent subjects from successfully performing trial activities or cause any subjects to end a trial before the 4 h time period was complete. However, PPE wear time duration did increase fatigue and reduce user acceptance. Future research efforts involving more sedentary subject activities and larger PPE CG shifts could provide more significant results and greater subjective response sensitivity.

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APPENDIX A
MEDICAL PRESCREEN QUESTIONNAIRE

MEDICAL HISTORY SCREEN

VOLUNTEER NAME____________________ AGE (18-55) _______
WEIGHT_________ (lbs)

TELEPHONE # ________________________________ DATE____________

1. Have you ever been a patient in the hospital? Yes No
Please explain:____

2. Have you ever had surgery? Yes No
Please explain:____

3. Are you now, or have you ever been, under the care of a physician or chiropractor for back/neck injury or disorder? Yes No
Please explain:____

4. Are you taking any medicine or pills? Yes No
(Prescription, over the counter or supplements)
Please explain:____

5. Do you use an inhaler now or any time in the past? Yes No

6. Do you have allergies to latex/rubber, medications, food, environmental products, etc.?
Please explain:____

7. Has your doctor ever said that you have a heart condition? Yes No

8. Do you feel pain in your chest when you do physical activity? Yes No

9. Have you ever lost your balance, felt dizzy or lost consciousness with exercise?
Yes No

10. Have you had or do you presently have any of the following conditions:
__ Rheumatic fever
__ Racing heart or irregular heart beat
__ Edema (swelling or ankles)
__ High blood pressure
__ Low blood pressure
__ Seizures
__ Lung disease (Emphysema, chronic bronchitis, Tuberculosis, etc.)
__ Heat attack

__ Fainting or dizziness
__ Diabetes
__ High cholesterol
__ Shortness of breath, wheezing or coughing at rest or with mild exertion
__ Chest pains
__ Palpitations or tachycardia (unusually strong or rapid heartbeat)
__ Calf cramping
__ Pain, discomfort in the chest, neck jaw, arms, or other areas
__ Heart murmur
__ Temporary loss of visual acuity or speech, or short-term numbness or weakness in one side, arm, or leg
__ Head injury or concussion
__ Severe Headaches
__ Asthma
__ Claustrophobia
__ Difficulty wearing masks or other devices that cover you face?
__ Anxiety
__ Stroke
__ Heart Failure

11. Have you ever had a spinal injury or condition such as: (**check below**)
_____ fracture/dislocation
_____ bulging, herniated, ruptured or compressed disk(s)
_____ Whiplash
_____ chronic/recurring neck or back pain
_____ painful or swollen joints, arthritis, or other muscle/skeletal disorder

12. Have you ever had surgery on your neck, back or extremities? Yes No
Please explain: ____

13. Do you currently smoke or use other tobacco products? Yes No

If Yes, how much? ____

____

14. Do you currently have any **other** chronic or recurrent medical problems? (For example: heart problems, stroke, cancer, diabetes) Yes No

If yes, describe: ____

____

15. Do you have any significant physical limitations? Yes No

If yes, describe: ____

16. **Female volunteers:** Are you, or could you possibly be, pregnant at this time? Yes No

17. Are you currently taking any medications (including inhalers, patches, or birth control pills)? Yes No

If so, what? ____

____

18. Do you have any artificial body parts, missing limbs or fingers? Yes No

If so, what? ____

____

19. How often, if ever, do you exercise? And what does it consist of?
(example: I run 3 miles every other day; or I lift weights for 1 hour every day etc.)

____

____

Additional comments:

____

____

Signature____________________________ Date____________

The above medical history has been reviewed and the volunteer is found to be:

(Medical Representative - circle one) **Physically Qualified / Not Physically Qualified** to participate in this study.

Reviewed by____________________________ Date____________

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APPENDIX B
GENERAL IMPACT CONSENT FORM

**** INFORMATION PROTECTED BY THE PRIVACY ACT OF 1974 ****

TITLE: Upper Thorax and Neck Muscle Fatigue Resulting from Prolonged Wear of Law Enforcement First Responders Chemical, Biological, Radiological, Nuclear (CBRN) Head-Borne Gear

1. Nature and purpose: You have been asked to volunteer to serve as a volunteer in the research project named above. The purpose of the study is to better understand human neck and thoracic response to wearing a First Responders Chemical, Biological, Radiological, Nuclear (CBRN) head-borne gear, consisting of an air purifying respirator (APR) and protective helmet, for 4 to 5 hr at a time. The total time requirement will be approximately 5 hr for each test session. You will be asked to participate in up to 10 sessions (8 regular sessions with the possibility of two additional make-up sessions). The study will take place in Bldg. 824, Area B, Wright-Patterson AFB, Ohio. There will be approximately 20 volunteers in this research effort.

2. Experimental procedures: If you decide to participate, you will be asked complete a medical screening questionnaire prior to selection. You will be asked to wear CBRN head-borne gear consisting of an APR and helmet weighing no more than 6.75 lbs. You may also be asked to wear experimental socks that are woven with silver fibers in place of your own socks. You will be asked to walk on a treadmill at different speeds (2-2.5 mph, 3-3.5 mph, and 2-2.5 mph and at an incline up to 6% grade) for 21 min of each hour you participate. You will be given a 3 min break after each 7 min spent on the treadmill. The rest of every hour will be spent making controlled movements with your head/neck and back, doing a visual search task, and having your neck strength and endurance measured. Your neck strength and endurance will be measured while seated by wearing a head harness attached to a loadcell by a strap and pulling rearward. You will have up to 8 Electromyography (EMG) contacts placed on your neck and upper torso area that will monitor your muscle activity during these strength/stamina sessions. For a few selected test configurations you will have a temperature sensor placed on the back of your calf. You will also be asked to complete a survey/questionnaire and visual tracking test before beginning the study, each hour of the study, then again after each 4-5 hour session. You may reposition your head gear and/or glasses (if applicable) at any time during the test, and will be allowed to use the rest room as needed. You well being will be monitored through every session, and at any time you report feeling pain, faint, dizzy, or shortness of breath, the session will be haulted. You may also choose to quit a test for any reason at any time.

3. Discomfort and risks: You may experience general fatigue as well as slight neck and/or back strain or discomfort, or other muscular soreness (thigh, knee, foot, etc.) due to the physical tasks that you may perform. You may also experience some discomfort in your neck (fatigue) and on your head (hot/itchy), and/or headaches due to weight of the head gear and duration that you will be wearing it. Although unlikely, it is also possible that you will experience neck muscle soreness lasting several days. This soreness may be compared to how your muscles feel after working-out after having not worked-out for a while. You could also experience elevated body temperature, dehydration, and/or loss of breath. You will perform stretching and isometric exercises as needed in order to minimize discomfort. You will be permitted to terminate the session at your own discretion. You will also be allowed to go to the rest room as needed, and can stretch at that time. You will receive drink provisions. Information will be collected from you in a medical questionnaire and evaluated by a medical monitor.

4. Precautions for female volunteers: If you are a female, you must read this section prior to signing the consent form. There is little information available concerning the response of female volunteers to prolonged wearing of helmets and respirator systems. However, female First Responders and other military members in the USAF and US Army may be volunteered to operational environments that include short and prolonged exposures to conditions necessitating the use of this equipment. Therefore, there is a real need to assess the effects of CBRN head-born gear on female body response for the improvement of exposure standards and design criteria for optimizing performance while minimizing discomfort and health risk. You should understand that there are several unique potential problems that must be considered for females being used as volunteers in these experiments.

a. Pregnancy - There are no data with which to evaluate the risk to a developing fetus (spontaneous abortion or fetal abnormalities) of exposure to extended wear of CBRN head-born gear during physically exerting activities. Pregnant females cannot participate in these studies. Pregnancy tests are offered to females of childbearing potential. It is appropriate to use an effective contraceptive technique prior to, and for the duration of, these exposures as a human volunteer. If you become pregnant or feel you might be pregnant, contact your provider and the study investigator or medical monitor.

b. Contraceptives - The use of oral contraceptives in the general population has been implicated in an observed increased incidence of medical problems such as inflammation of the large veins in the legs and pelvis with formation of blood clots. These clots may be dislodged and travel to the lungs with a potentially fatal outcome. Current medical studies examine these problems in a normal environment. Medical studies have also suggested that smoking and the use of oral contraceptives place the female volunteer at a greater risk. No studies have been done to examine the influence, if any, of wearing of CBRN head-born gear during physically exerting activities on the use of oral or intrauterine contraceptives.

c. Ovarian Abnormalities - The ovary is volunteer to cystic enlargement and other conditions that may occur with or without symptoms. There is a possibility that prolonged exposures to physically exerting activities could increase the normal risk that such an enlarged cyst may burst or that the ovary may twist about its support, cutting off the blood supply. This situation would possibly require major surgery to correct the condition with the attendant risks of loss of the involved ovary, bleeding, infection, or death.

d. Menstrual Flow - Prolonged exposures to physically exerting activities could theoretically result in menstrual flow alterations.

e. Breast Support - The forces experienced during the physically exerting activities under this protocol indicate that breast support should be used. The presence of breast implants precludes participation in this protocol.

5. Benefits: You are not expected to benefit directly from my participating, but the Air Force and Army expect to better understand the relationship between prolonged wear of head gear, fatigue, performance, and increase comfort and effectiveness and reduce the risk of fatigue or injury through this research.

6. Compensation: You will be compensated for your participation in this project at the rate of $12.50 per hour. However, if you are a military member, you cannot be compensated with DoD funds for research participation (AFI 40-402 3.3.1.) therefore military members that wish to participate must do so without compensation, and with their Commanders' approval.

7. Alternatives: Choosing not to participate is an alternative to volunteering for this study.

8. Entitlements and confidentiality:

a) Records of your participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations. Your personal information will be stored in a locked cabinet in an office that is locked when not occupied. Electronic files containing your personal information will be password protected and stored only on a DoD server. It is intended that the only people having access to your information will be the researchers named above and the AFRL Wright Site IRB or any other IRB involved in the review and approval of this protocol. When no longer needed for research purposes your information will be destroyed in a secure manner (shredding). Complete confidentiality for military personnel cannot be promised because information bearing on your health may be required to be reported to appropriate medical or command authorities.

b) Your entitlements to medical and dental care and/or compensation in the event of injury are governed by federal laws and regulations, and that if you desire further information you may contact the base legal office (88 ABW/JA, 257-6142). In the event of a research related injury, you may contact the medical monitor of this study.

c) If an unanticipated event (medical misadventure) occurs during your participation in this study, you will be informed. If you are not competent at the time to understand the nature of the event, such information will be brought to the attention of your next of kin or other emergency contact, indicated below:

______________________________ _______________
NAME (Emergency Contact) PHONE

d) The decision to participate in this research is completely voluntary on your part. No one has coerced or intimidated you into participating in this program. You are participating because you want to. The principal investigator or one of the associate investigators, has adequately answered any and all questions you have about this study, your participation, and the procedures involved. You understand that the principal investigator or one of the associate investigators, will be available to answer any questions concerning procedures throughout this study. If significant new findings develop during the course of this research, which may relate to your decision to continue participation, you will be informed. You further understand that you may withdraw this consent at any time and discontinue further participation in this study without prejudice to your entitlements. The investigator or medical monitor of this study may terminate your participation in this study if she or he feels this to be in your best interest. If you have any questions or concerns about your participation in this study or your rights as a research volunteer, you can contact The AFRL Wright Site Institutional Review Board Chairman at (937) 904-8100.

e) Your participation in this study may be photographed, filmed or audio/videotaped. You consent to the use of these media for training and data collection purposes, and for use in scientific presentations, publications, and data bases. Any release of your participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations. This means that personal information will not be released to unauthorized sources without your permission. These media may be used for presentation and/or publication.

f) Statistical data collected during the test program may be published in the scientific literature without identifying the names of the volunteers.

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

VOLUNTEER SIGNATURE SSAN (OPTIONAL) DATE

VOLUNTEER NAME (Printed)

ADVISING INVESTIGATOR SIGNATURE DATE

INVESTIGATOR NAME (Printed)

WITNESS SIGNATURE DATE

WITNESS NAME (Printed)

Privacy Act Statement
Authority: We are requesting disclosure of your Social Security Number above. Researchers are authorized to collect personal information (including social security numbers) on research volunteers under Privacy Act Record Notice F 080 AFMC A found at AFI 37-144, pages 257-258.
Purpose: It is possible that latent risks or injuries inherent in this experiment will not be discovered until sometime in the future. The purpose of collecting your Social Security Number is to aid researchers in locating you at a future date if further disclosures are appropriate.
Routine Uses: Personal information gathered in this study may be disclosed (including in some cases your name and Social Security Number) for any of the blanket routine uses published by the Air Force at AFDIR 37-144, Section B, and reprinted in the Federal Register at 52 FR 16431.
Disclosure: Disclosure of your Social Security Number is voluntary. You will not be excluded from participation in this study because you do not wish to disclose or do not disclose your social security number. No adverse action whatsoever will be taken against you, and no privilege will be denied you based on the fact you do not disclose your Social Security Number.

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APPENDIX C
HEADGEAR CONFIGURATION PHOTOGRAPHS

Configuration	Helmet	Respirator	Filter Placement	Photograph
A	No	No	None	
B	PASGT	Yes	Left Side Mask	
C	PASGT	Yes	Front of Mask	
D	PASGT	Yes	Back of Helmet	

E	None	Yes	Left Side Mask	
F	None	Yes	Front of Mask	
G	PASGT	None	Back of Helmet	
H	PASGT	Yes	Left Upper Arm	

APPENDIX D
QUESTIONNAIRES
(Pre-test, hourly, post-test)

PRE-TEST:

1. Were you able to complete the suggested warm-up exercises? Yes No

2. Do you have any medical complaints? (For example: headache, sore muscles) Yes No

If Yes, please explain:____

3. What type of shoes are you wearing today? (For example: boots, running shoes, sneakers, other): ____

4. Are these the same shoes that you wore during the last testing session? Yes No

5. Have you modified the shoes you are wearing today? (For example by adding inserts, insoles, or orthotic devices? Yes No

If Yes, please explain:____

6. Are you using any bandages, moleskin, petroleum jelly, or powders on your feet? Yes No

If Yes, please explain:____

7. Do you presently have any of these foot conditions:

   Blisters Yes No

If Yes, explain:____

   Painful or swollen feet Yes No

If Yes, explain:____

8. Do you need to speak with the Medical Monitor before the start of today's session? Yes No

9. Is there any reason why you should not participate in today's session? Yes No

HOURLY:

1. According to the scale, select a number that corresponds to each body parts' level of fatigue/weakness at this time.

No Fatigue			Moderate Fatigue			Severe Fatigue
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back
Lower Back

2. According to the scale, select a number that corresponds to each body parts' level of pain/ache at this time.

No Pain			Moderate Pain			Severe Pain
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back
Lower Back

3. According to the scale, select a number that corresponds to any numbness or loss of sensation at this time.

No Numbness			Moderate Numbness		Severe Numbness	
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back
Lower Back

4. According to the scale, select a number that corresponds to "hot spots" associated with the helmet and/or respirator at this time.

No Hot Spots			Moderate Hot Spots		Severe Hot Spots	
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back

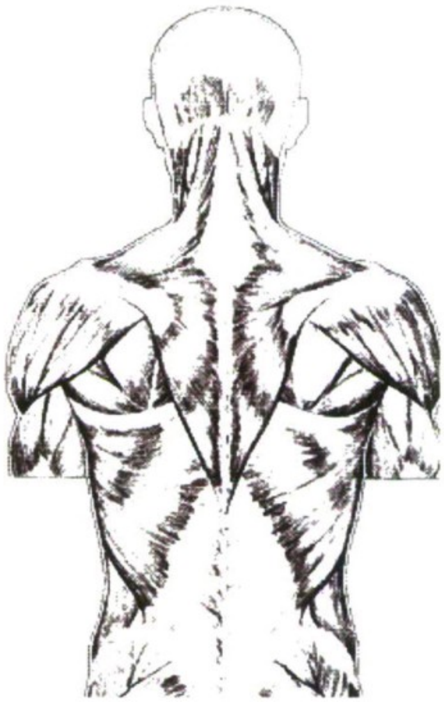
5. According to the scale, select a number that corresponds to the amount of perspiration/sweat associated with the helmet and/or respirator at this time.

No Sweat			Moderate Sweat			Severe Sweat
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back

6. According to the scale, select a number that corresponds to the level of difficulty keeping your head/chin up associated with the helmet and/or respirator at this time.

No Difficulty			Moderate Difficulty		Severe Difficulty	
0	1	2	3	4	5	6



7. Please rate your current perceived level of exertion using the scale below:

6	Very, very light
5	Very light
4	Fairly light
3	Somewhat hard
2	Hard
1	Very hard
0	Very, very hard

8. Right now, this respirator and helmet combination is:

6	Very, very comfortable
5	Very comfortable
4	Fairly comfortable
3	Comfortable
2	Fairly uncomfortable
1	Very uncomfortable
0	Very, very uncomfortable

POST-TEST

1. According to the scale, select a number that corresponds to each body parts' level of fatigue/weakness at this time.

No Fatigue			Moderate Fatigue		Severe Fatigue	
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back
Lower Back

2. According to the scale, select a number that corresponds to each body parts' level of pain/ache at this time.

No Pain			Moderate Pain			Severe Pain
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back
Lower Back

3. According to the scale, select a number that corresponds to any numbness or loss of sensation at this time.

No Numbness			Moderate Numbness		Severe Numbness	
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back
Lower Back

4. According to the scale, select a number that corresponds to "hot spots" associated with the helmet and/or respirator at this time.

No Hot Spots			Moderate Hot Spots		Severe Hot Spots	
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back

5. According to the scale, select a number that corresponds to the amount of perspiration/sweat associated with the helmet and/or respirator at this time.

No Sweat			Moderate Sweat			Severe Sweat
0	1	2	3	4	5	6

Head
Neck
Upper/Middle Back

6. According to the scale, select a number that corresponds to the level of difficulty keeping your head/chin up associated with the helmet and/or respirator at this time.

No Difficulty			Moderate Difficulty			Severe Difficulty
0	1	2	3	4	5	6

7. Do you have any medical complaints? (For example: headache, sore muscles) Yes No
   If Yes, please explain:____

8. Do you need to speak with the medical monitor at this time? Yes No

APPENDIX E
TEST CONDUCTOR'S CHECKLIST

AIR FORCE RESEARCH LABORATORY **BIOMECHANICS BRANCH** **WRIGHT PATTERSON AFB OHIO**	**CBRN** **TEST CONDUCTOR'S CHECKLIST**	
APPROVED BY: Chris Albery		
Volunteer ID		
Date		
Time Start		
Cell		
Photo on treadmill or neck strength device with photo board		
Inform Volunteer about Procedures		
Does the Volunteer have any Medical Complaints?		
Does Volunteer Need to Talk to the Medical Monitor?		
Is There Any Reason Why the Volunteer Should not Participate in Today's Study?		
Has Volunteer Completed Head/Neck Warm-Up Exercises?		
Complete Pre-test Questionnaire		
File Name for Pre-test Questionnaire		
Prep Skin		
Fit Volunteer with 2 Electrodes, 1 Ground	EMG Set:	EMG Set:
Fit Volunteer with Respirator		
Pre Test 100% MVC EMG		
Perform 100% MVC EMG		
45 sec Rest Period		
Perform 100% MVC EMG		
45 sec Rest Period		
Perform 100% MVC EMG		
45 sec Rest Period		
Record Peak From the Three 100% NS		
Calculate and Record 70 % MVC		

File Name for the Peak 100% NS		
File Name for 100% EMG		
Fit Volunteer with Helmet		
Treadmill – Hour 1		
2.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
2.0 mph w/incline of 6% (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
3.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
Complete Visual Task – Hour 1		
File Name for Visual Task		
Controlled Movements – Hour 1		
Standing with Head Motions (2 min)		
Hands/Knees with Head Motions (2 min)		
Sit/Stand (2 min)		
Draw, sight, holster pistol (2 min)		
Complete Questionnaire – Hour 1		
File Name for Questionnaire		
70% Static Strength EMG – Hour 1		
File Name for 70% Static Strength		
File Name for 70% EMG		
HOUR 2	**HOUR 2**	**HOUR 2**
Treadmill – Hour 2		
2.0 mph w/incline of 6% (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		

Break (3 min)		
3.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
2.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
Complete Visual Task – Hour 2		
File Name for Visual Task		
Controlled Movements – Hour 2		
Sit/Stand (2 min)		
Hands/Knees with Head Motions (2 min)		
Draw, sight, holster pistol (2 min)		
Standing with Head Motions (2 min)		
Complete Questionnaire – Hour 2		
File Name for Questionnaire		
70% Static Strength EMG – Hour 2		
File Name for 70% Static Strength		
File Name for 70% EMG		
HOUR 3	**HOUR 3**	**HOUR 3**
Treadmill – Hour 3		
3.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
2.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
2.0 mph w/incline of 6% (7 min)		
Collect Heart Rate (0 minutes)		

Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
Complete Visual Task – Hour 3		
File Name for Visual Task		
Controlled Movements – Hour 3		
Draw, sight, holster pistol (2 min)		
Standing with Head Motions (2 min)		
Hands/Knees with Head Motions (2 min)		
Sit/Stand (2 min)		
Complete Questionnaire – Hour 3		
File Name for Questionnaire		
70% Static Strength EMG – Hour 3		
File Name for 70% Static Strength		
File Name for 70% EMG		
HOUR 4	**HOUR 4**	**HOUR 4**
Treadmill – Hour 4		
2.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
3.0 mph (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
2.0 mph w/incline of 6% (7 min)		
Collect Heart Rate (0 minutes)		
Collect Heart Rate (2.5 minutes)		
Collect Heart Rate (5 minutes)		
Collect Heart Rate (7 minutes)		
Break (3 min)		
Complete Visual Task – Hour 4		
File Name for Visual Task		
Controlled Movements – Hour 4		
Hands/Knees with Head Motions (2 min)		
Sit/Stand (2 min)		
Standing with Head Motions (2 min)		
Draw, sight, holster pistol (2 min)		

Complete Questionnaire – Hour 4		
File Name for Questionnaire		
70% Static Strength EMG – Hour 4		
File Name for 70% Static Strength		
File Name for 70% EMG		
Post Test 100% MVC EMG		
Perform 100% MVC EMG		
45 sec Rest Period		
Perform 100% MVC EMG		
45 sec Rest Period		
Perform 100% MVC EMG		
45 sec Rest Period		
Record Peak From the Three 100% NS		
File Name for the Peak 100% NS		
File Name for 100% EMG		
Complete Post Test Questionnaire		
File Name for Post Test Questionnaire		
Does the Volunteer Have any Medical Complaints (headache, sore muscles)?		
Does the Volunteer Need to Talk to the Medical Monitor?		
Remind Volunteer to Perform Cool Down Exercises		
Schedule Next Test Session		
Time Finished		
Pay Volunteer		
Copy All Files to Network		
Test Conductor(s)		

Blank

APPENDIX F
EMG DATA ANALYSIS

The design of the test did not support full factorial analysis for all the variables used. Namely:

- Filter Placement 4 Possible
- Respirator 2 Possible
- Helmet 2 Possible

The following were compared:

- A vs. All Combinational significance
- B vs. C vs. D vs. H Filter placement Influence
- E vs. F Filter placement Influence
- D vs. G Respirator Influence

General Linear Model (Omnibus) for A thru H Configurations

The first test was an omnibus across all configurations looking for relevant statistical differences. The variables being considered the configurations themselves. The stat program couldn't do the comparison however because of the lack of converted data at the time this report was delivered. Eight variables need at least eight complete data sets. There were only seven complete data sets at the time of analyses.

Descriptive for all Data

The descriptive tests showed a high SD vs. the statistical measure.

Ex. Arms_1 = 0.000778 SD = .000463

High SD is the trend across all of the data.

Table 5. EMG descriptive statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Arms_1	18	.00019788	.00199940	.0007777972	.00010919680	.00046328277	.000
Arms_2	20	.00012505	.00111070	.0006486510	.00007310578	.00032693899	.000
Arms_3	18	.00016275	.00125880	.0006580156	.00007133702	.00030265735	.000
Arms_4	17	.00017650	.00179930	.0007798194	.00011331502	.00046720981	.000
Afrq_1	18	15.0	61.0	31.139	2.9185	12.3822	153.318
Afrq_2	20	2	43	23.98	2.245	10.041	100.828
Afrq_3	18	17.0	40.0	24.722	1.5212	6.4540	41.654
Afrq_4	17	18	61	31.53	3.428	14.136	199.827
Brms_1	15	.00	.00	.0007	.00008	.00032	.000
Brms_2	17	.00027906	.00181030	.0007522641	.00010161039	.00041895038	.000
Brms_3	16	.00017898	.00196270	.0007701081	.00012645458	.00050581834	.000
Brms_4	16	.00015895	.00157110	.0006061519	.00009119296	.00036477185	.000
Bfrq_1	15	15.00	43.00	26.1333	2.53990	9.83700	96.767
Bfrq_2	17	15.0	45.0	27.147	2.5516	10.5205	110.680

Bfrq_3	16	15	43	25.00	2.178	8.714	75.933
Bfrq_4	16	14.0	61.0	27.500	2.7481	10.9924	120.833
Crms_1	16	.00031447	.00193010	.0008247187	.00012219808	.00048879232	.000
Crms_2	16	.00019616	.00343860	.0011289269	.00022988862	.00091955448	.000
Crms_3	15	.00027616	.00161220	.0007706320	.00010175140	.00039408147	.000
Crms_4	16	.00025851	.00190350	.0007878750	.00013009601	.00052038403	.000
Cfrq_1	16	17	61	27.72	3.191	12.763	162.899
Cfrq_2	16	17.0	61.0	28.656	3.1064	12.4254	154.391
Cfrq_3	15	17.0	61.0	27.067	2.7654	10.7103	114.710
Cfrq_4	16	18.0	61.0	28.875	3.0113	12.0451	145.083
Drms_1	16	.00022683	.00210970	.0007994250	.00012459732	.00049838929	.000
Drms_2	16	.00019676	.00175850	.0008586313	.00010586943	.00042347771	.000
Drms_3	15	.00021560	.00181110	.0008136013	.00011742010	.00045476609	.000
Drms_4	15	.00	.00	.0007	.00010	.00038	.000
Dfrq_1	16	15	47	27.25	2.574	10.296	106.000
Dfrq_2	16	16.0	36.5	23.906	1.6603	6.6413	44.107
Dfrq_3	15	15.0	41.5	23.900	1.8563	7.1893	51.686
Dfrq_4	15	12.50	48.00	25.9000	2.41138	9.33924	87.221
Erms_1	15	.00036764	.00218300	.0009596867	.00014881167	.00057634512	.000
Erms_2	16	.00024013	.00180930	.0009306719	.00012981716	.00051926866	.000
Erms_3	15	.00033366	.00194110	.0009729307	.00012058905	.00046703937	.000
Erms_4	16	.00019761	.00116460	.0006861431	.00007840941	.00031363764	.000
Efrq_1	15	15.5	61.0	27.700	3.6635	14.1885	201.314
Efrq_2	16	5.5	39.5	22.656	2.2438	8.9754	80.557
Efrq_3	15	15	32	23.70	1.403	5.434	29.529
Efrq_4	16	18.0	50.5	28.344	2.2619	9.0475	81.857
Frms_1	15	.00026597	.00115010	.0007220560	.00008158259	.00031596801	.000
Frms_2	15	.00025078	.00167600	.0007724107	.00011955094	.00046301879	.000
Frms_3	14	.00024467	.00128540	.0007278750	.00009222533	.00034507559	.000
Frms_4	13	.00030171	.00254040	.0009448223	.00016560857	.00059711018	.000
Ffrq_1	15	18	52	24.83	2.226	8.620	74.310
Ffrq_2	15	17.0	61.0	28.033	2.8433	11.0121	121.267
Ffrq_3	14	15.0	39.0	25.143	2.0078	7.5126	56.440
Ffrq_4	13	18	32	24.73	1.414	5.097	25.984
Grms_1	13	.00	.00	.0008	.00013	.00048	.000
Grms_2	16	.00026916	.00262190	.0008907331	.00014459001	.00057836004	.000
Grms_3	16	.00021914	.00152970	.0006819125	.00008565345	.00034261379	.000
Grms_4	16	.00038499	.00180780	.0009613387	.00010708107	.00042832428	.000
Gfrq_1	13	10.00	61.00	27.0385	3.68967	13.30329	176.978

Gfrq_2	16	12	61	26.47	2.909	11.637	135.416
Gfrq_3	16	15	38	25.09	1.495	5.981	35.774
Gfrq_4	16	16.0	61.0	26.531	2.8528	11.4112	130.216
Hrms_1	16	.00018472	.00148130	.0006323875	.00010246382	.00040985526	.000
Hrms_2	14	.00028410	.00139300	.0007133686	.00008548479	.00031985479	.000
Hrms_3	16	.00018890	.00143080	.0006798788	.00009795121	.00039180485	.000
Hrms_4	16	.00015482	.00178780	.0007805556	.00013060476	.00052241906	.000
Hfrq_1	16	15.5	31.0	21.250	.9832	3.9328	15.467
Hfrq_2	14	16	52	27.50	2.947	11.026	121.577
Hfrq_3	16	16.0	37.0	24.656	1.4199	5.6796	32.257
Hfrq_4	16	16	61	27.31	2.715	10.861	117.963
Arms_41	16	.00	.00	.0000	.00015	.00059	.000
Brms_41	14	.00	.00	-.0001	.00010	.00037	.000
Crms_41	16	.00	.00	.0000	.00009	.00036	.000
Drms_41	15	.00	.00	-.0001	.00008	.00030	.000
Erms_41	15	.00	.00	-.0003	.00015	.00058	.000
Frms_41	13	.00	.00	.0002	.00014	.00050	.000
Grms_41	13	.00	.00	.0002	.00017	.00061	.000
Hrms_41	16	.00	.00	.0001	.00011	.00043	.000
Afrq_41	16	-19.50	44.00	2.0625	4.13896	16.55584	274.096
Bfrq_41	14	-22.50	40.50	.6786	4.58815	17.16728	294.716
Cfrq_41	16	-29.50	25.00	1.1563	3.51210	14.04839	197.357
Dfrq_41	15	-20.50	27.00	-.0333	2.88612	11.17789	124.945
Efrq_41	15	-35.50	20.50	.0333	3.93624	15.24498	232.410
Ffrq_41	13	-27.50	10.00	-.5385	2.64057	9.52073	90.644
Gfrq_41	13	-22.00	14.00	.9615	2.53151	9.12748	83.311
Hfrq_41	16	-12.00	37.50	6.0625	2.96292	11.85169	140.463
Valid N (listwise)	5						

T-Test for All Configurations (B-H) vs. Control (A) Over Time. The change from Hour 1 to Hour 4 is abbreviated as 41.

RMS

Drms_41 < Arms_41 $p < 0.05$

Hrms_41 = Arms_41 $p < 0.05$

Frms_41 > Arms_41 $p < 0.1$

Table 6. T-Test (change from hr4 - hr1) RMS

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	**Arms_41**	.0001	12	.00065	.00019

	Brms_41	.0000	12	.00027	.00008
Pair 2	**Arms_41**	.0001	13	.00060	.00017
	Crms_41	-.0001	13	.00018	.00005
Pair 3	**Arms_41**	.0001	11	.00061	.00018
	Drms_41	-.0002	11	.00034	.00010
Pair 4	**Arms_41**	.0002	11	.00061	.00018
	Erms_41	-.0003	11	.00059	.00018
Pair 5	**Arms_41**	.0001	10	.00053	.00017
	Frms_41	.0003	10	.00057	.00018
Pair 6	**Arms_41**	.0002	9	.00068	.00023
	Grms_41	.0002	9	.00067	.00022
Pair 7	**Arms_41**	.0001	12	.00065	.00019
	Hrms_41	.0001	12	.00042	.00012

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	**Arms_41 & Brms_41**	12	-.119	.713
Pair 2	**Arms_41 & Crms_41**	13	.126	.682
Pair 3	**Arms_41 & Drms_41**	11	.690	.019
Pair 4	**Arms_41 & Erms_41**	11	.105	.758
Pair 5	**Arms_41 & Frms_41**	10	.554	.096
Pair 6	**Arms_41 & Grms_41**	9	-.024	.951
Pair 7	**Arms_41 & Hrms_41**	12	.663	.019

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	**Arms_41 - Brms_41**	.00008	.00073	.00021	-.00038	.00055	.392	11	.702
Pair 2	**Arms_41 - Crms_41**	.00023	.00061	.00017	-.00014	.00060	1.364	12	.198
Pair 3	**Arms_41 - Drms_41**	.00032	.00045	.00014	.00002	.00062	2.346	10	.041
Pair 4	**Arms_41 - Erms_41**	.00045	.00081	.00024	-.00009	.00099	1.841	10	.095
Pair 5	**Arms_41 - Frms_41**	-.00021	.00052	.00016	-.00058	.00016	-1.308	9	.223
Pair 6	**Arms_41 - Grms_41**	.00003	.00097	.00032	-.00072	.00077	.078	8	.940

Pair 7	Arms_41 - Hrms_41	-.00003	.00049	.00014	-.00034	.00029	-.180	11	.860

FREQUENCY

H_frq41 > Afrq_41 $p < 0.05$

Table 7. T-Test (change from hr4 - hr1) FREQUENCY

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Afrq_41	5.0833	12	17.57301	5.07289
	Bfrq_41	.7083	12	18.65166	5.38427
Pair 2	Afrq_41	1.2692	13	18.38321	5.09858
	Cfrq_41	-.9615	13	13.92309	3.86157
Pair 3	Afrq_41	3.1818	11	19.12495	5.76639
	Dfrq_41	1.5000	11	12.15319	3.66432
Pair 4	Afrq_41	1.2727	11	20.11264	6.06419
	Efrq_41	-.1364	11	17.82146	5.37337
Pair 5	Afrq_41	-.7500	10	18.00193	5.69271
	Ffrq_41	-.7500	10	9.97566	3.15458
Pair 6	Afrq_41	5.2222	9	20.74716	6.91572
	Gfrq_41	-1.1111	9	9.48939	3.16313
Pair 7	Afrq_41	2.9583	12	18.69426	5.39657
	Hfrq_41	4.2917	12	9.62114	2.77738

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Afrq_41 & Bfrq_41	12	.256	.422
Pair 2	Afrq_41 & Cfrq_41	13	-.140	.649
Pair 3	Afrq_41 & Dfrq_41	11	-.253	.453
Pair 4	Afrq_41 & Efrq_41	11	.070	.838
Pair 5	Afrq_41 & Ffrq_41	10	-.171	.637
Pair 6	Afrq_41 & Gfrq_41	9	.576	.105
Pair 7	Afrq_41 & Hfrq_41	12	.604	.038

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			

Pair 1	Afrq_41 - Bfrq_41	4.37500	22.10936	6.38242	-9.67262	18.42262	.685	11	.507
Pair 2	Afrq_41 - Cfrq_41	2.23077	24.56167	6.81218	-12.61170	17.07324	.327	12	.749
Pair 3	Afrq_41 - Dfrq_41	1.68182	25.12198	7.57456	-15.19535	18.55899	.222	10	.829
Pair 4	Afrq_41 - Efrq_41	1.40909	25.92279	7.81601	-16.00607	18.82426	.180	10	.861
Pair 5	Afrq_41 - Ffrq_41	.00000	22.02272	6.96419	-15.75410	15.75410	.000	9	1.000
Pair 6	Afrq_41 - Gfrq_41	6.33333	17.14278	5.71426	-6.84378	19.51044	1.108	8	.300
Pair 7	Afrq_41 - Hfrq_41	-1.33333	14.99141	4.32765	-10.85842	8.19176	-.308	11	.764

General Linear Model (Omnibus) for Configurations BCDH) **Filter Placement
No significant correlations could be made.

Table 8. General linear model (Omnibus ANOVA on BCDH) RMS

Within-Volunteers Factors
Measure: MEASURE_1

bedh	Dependent Variable
1	Brms_41
2	Crms_41
3	Drms_41
4	Hrms_41

Descriptive Statistics

	Mean	Std. Deviation	N
Brms_41	.0000	.00028	11
Crms_41	-.0001	.00009	11
Drms_41	-.0001	.00034	11
Hrms_41	.0001	.00043	11

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
bedh	Pillai's Trace	.551	3.268(a)	3.000	8.000	.080
	Wilks' Lambda	.449	3.268(a)	3.000	8.000	.080
	Hotelling's Trace	1.226	3.268(a)	3.000	8.000	.080
	Roy's Largest Root	1.226	3.268(a)	3.000	8.000	.080
a Exact statistic						
b Design: Intercept Within Volunteers Design: bedh						

Mauchly's Test of Sphericity(b)
Measure: MEASURE_1

Within Volunteers Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
bcdh	.326	9.790	5	.083	.609	.738	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Volunteers Effects table.

b Design: Intercept
Within Volunteers Design: bcdh

Tests of Within-Volunteers Effects
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
bcdh	Sphericity Assumed	.000	3	.000	1.734	.181
	Greenhouse-Geisser	.000	1.826	.000	1.734	.206
	Huynh-Feldt	.000	2.213	.000	1.734	.198
	Lower-bound	.000	1.000	.000	1.734	.217
Error(bcdh)	Sphericity Assumed	.000	30	.000		
	Greenhouse-Geisser	.000	18.264	.000		
	Huynh-Feldt	.000	22.133	.000		
	Lower-bound	.000	10.000	.000		

Tests of Within-Volunteers Contrasts
Measure: MEASURE_1

Source	bcdh	Type III Sum of Squares	df	Mean Square	F	Sig.
bcdh	Linear	.000	1	.000	.424	.530
	Quadratic	.000	1	.000	12.210	.006
	Cubic	.000	1	.000	1.140	.311
Error(bcdh)	Linear	.000	10	.000		
	Quadratic	.000	10	.000		
	Cubic	.000	10	.000		

Tests of Between-Volunteers Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	.000	1	.000	.202	.663
Error	.000	10	.000		

Estimated Marginal Means

bcdh

Estimates
Measure: MEASURE_1

bcdh	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.000	.000	.000	.000
2	.000	.000	.000	.000
3	.000	.000	.000	.000
4	.000	.000	.000	.000

Pairwise Comparisons
Measure: MEASURE_1

(I) bcdh	(J) bcdh	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	.000	.000	.513	.000	.000
	3	.000	.000	.284	.000	.000
	4	.000	.000	.438	-.001	.000
2	1	.000	.000	.513	.000	.000
	3	.000	.000	.517	.000	.000
	4	.000	.000	.133	-.001	.000
3	1	.000	.000	.284	.000	.000
	2	.000	.000	.517	.000	.000
	4	.000(*)	.000	.049	-.001	.000
4	1	.000	.000	.438	.000	.001
	2	.000	.000	.133	.000	.001
	3	.000(*)	.000	.049	.000	.001

Based on estimated marginal means
* The mean difference is significant at the .05 level.
a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.551	3.268(a)	3.000	8.000	.080
Wilks' lambda	.449	3.268(a)	3.000	8.000	.080
Hotelling's trace	1.226	3.268(a)	3.000	8.000	.080
Roy's largest root	1.226	3.268(a)	3.000	8.000	.080

Each F tests the multivariate effect of bcdh. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a Exact statistic

Table 9. General linear model (Omnibus ANOVA on BCDH) FREQUENCY

Within-Volunteers Factors
Measure: MEASURE_1

bcdh	Dependent Variable
1	Bfrq_41
2	Cfrq_41
3	Dfrq_41
4	Hfrq_41

Descriptive Statistics

	Mean	Std. Deviation	N
Bfrq_41	3.0909	17.95664	11
Cfrq_41	2.2727	9.83454	11
Dfrq_41	-2.3636	9.75472	11
Hfrq_41	4.9091	9.59119	11

Multivariate Tests(b)

Effect		Value	F	Hypothesis df	Error df	Sig.
bcdh	Pillai's Trace	.306	1.176(a)	3.000	8.000	.378
	Wilks' Lambda	.694	1.176(a)	3.000	8.000	.378
	Hotelling's Trace	.441	1.176(a)	3.000	8.000	.378
	Roy's Largest Root	.441	1.176(a)	3.000	8.000	.378

a Exact statistic

b Design: Intercept
Within Volunteers Design: bcdh

Mauchly's Test of Sphericity(b)
Measure: MEASURE_1

Within Volunteers Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
bcdh	.431	7.350	5	.198	.676	.849	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Volunteers Effects table.

b Design: Intercept
Within Volunteers Design: bcdh

Tests of Within-Volunteers Effects
Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
bcdh	Sphericity Assumed	316.432	3	105.477	.756	.528

	Greenhouse-Geisser	316.432	2.028	156.046	.756	.484
	Huynh-Feldt	316.432	2.547	124.233	.756	.509
	Lower-bound	316.432	1.000	316.432	.756	.405
Error(bcdh)	Sphericity Assumed	4184.818	30	139.494		
	Greenhouse-Geisser	4184.818	20.278	206.372		
	Huynh-Feldt	4184.818	25.471	164.298		
	Lower-bound	4184.818	10.000	418.482		

Tests of Within-Volunteers Contrasts
Measure: MEASURE_1

Source	bcdh	Type III Sum of Squares	df	Mean Square	F	Sig.
bcdh	Linear	.368	1	.368	.004	.952
	Quadratic	180.023	1	180.023	.752	.406
	Cubic	136.041	1	136.041	1.639	.229
Error(bcdh)	Linear	959.832	10	95.983		
	Quadratic	2394.727	10	239.473		
	Cubic	830.259	10	83.026		

Tests of Between-Volunteers Effects
Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	172.023	1	172.023	.916	.361
Error	1878.227	10	187.823		

Estimated Marginal Means

bcdh

Estimates
Measure: MEASURE_1

bcdh	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.091	5.414	-8.973	15.154
2	2.273	2.965	-4.334	8.880
3	-2.364	2.941	-8.917	4.190
4	4.909	2.892	-1.534	11.353

Pairwise Comparisons
Measure: MEASURE_1

(I) bcdh	(J) bcdh	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	.818	6.057	.895	-12.678	14.314

	3	5.455	6.519	.422	-9.071	19.980
	4	-1.818	3.769	.640	-10.216	6.580
2	1	-.818	6.057	.895	-14.314	12.678
	3	4.636	4.283	.304	-4.906	14.179
	4	-2.636	4.694	.587	-13.096	7.823
3	1	-5.455	6.519	.422	-19.980	9.071
	2	-4.636	4.283	.304	-14.179	4.906
	4	-7.273	4.290	.121	-16.832	2.287
4	1	1.818	3.769	.640	-6.580	10.216
	2	2.636	4.694	.587	-7.823	13.096
	3	7.273	4.290	.121	-2.287	16.832

Based on estimated marginal means

a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.306	1.176(a)	3.000	8.000	.378
Wilks' lambda	.694	1.176(a)	3.000	8.000	.378
Hotelling's trace	.441	1.176(a)	3.000	8.000	.378
Roy's largest root	.441	1.176(a)	3.000	8.000	.378

Each F tests the multivariate effect of bedh. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a Exact statistic

T-Test for D vs. G from Hour 1 to Hour 4 **Respirator

No significant correlations could be for RMS, however, there is a strong correlation between frequencies.

FREQ

Gfreq_41 > Dfrq_41 $p < .05$

Table 10. T-Test (D & G ((hr4 - hr1)) RMS

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Drms_41	-.0001	13	.00031	.00009
	Grms_41	.0002	13	.00061	.00017

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Drms_41 & Grms_41	13	-.125	.685

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Drms_41 - Grms_41	-.00035	.00071	.00020	-.00078	.00009	-1.748	12	.106

Table 11. T-Test (D & G ((hr4 - hr1)) FREQUENCY

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Dfrq_41	-1.4231	13	11.38868	3.15865
	Gfrq_41	.9615	13	9.12748	2.53151

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Dfrq_41 & Gfrq_41	13	-.567	.043

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Dfrq_41 - Gfrq_41	-2.38462	18.19015	5.04504	-13.37681	8.60758	-.473	12	.645

T-Test for E vs. F from Hour 1 to Hour 4 **Filter Placement

Hrms_1 < Arms_1 $p < 0.05$

Table 12. T-Test (E & F ((hr4 - hr1)) RMS & FRQ

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Erms_41	-.0002	12	.00058	.00017
	Frms_41	.0002	12	.00052	.00015
Pair 2	Efrq_41	-1.4583	12	16.50958	4.76591
	Ffrq_41	-.3333	12	9.91402	2.86193

Paired Samples Correlations

		N	Correlation	Sig.

Pair 1	Erms_41 & Frms_41	12	-.097	.764
Pair 2	Efrq_41 & Ffrq_41	12	-.169	.599

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Erms_41 - Frms_41	-.00044	.00082	.00024	-.00096	.00008	-1.870	11	.088
Pair 2	Efrq_41 - Ffrq_41	-1.12500	20.64761	5.96045	-14.24387	11.99387	-.189	11	.854

T-Test for All Configurations (B-H) vs. Control (A) at Hour 1 & Hour 4

Drms_1 approx = Arms_1	$p < 0.005$
Hrms_1 < Arms_1	$p < 0.05$
Frms_4 > Arms_4	$p < 0.05$
Grms_4 > Arms_4	$p < 0.05$
Hrms_4 < Arms_4	$p < 0.005$
Grms_4 < Arms_4	$p < 0.05$

Table 13. T-Test (All Config ((hr1 & hr4)) RMS & FRQ

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Arms_1	.0008072421	14	.00048377190	.00012929348
	Brms_1	.0007	14	.00032	.00009
Pair 2	Arms_1	.0008448557	14	.00045585097	.00012183130
	Crms_1	.0008351071	14	.00052390405	.00014001925
Pair 3	Arms_1	.0007976850	14	.00045426192	.00012140661
	Drms_1	.0008178229	14	.00053223012	.00014224448
Pair 4	Arms_1	.0007518069	13	.00043775253	.00012141071
	Erms_1	.0010193469	13	.00059879340	.00016607541
Pair 5	Arms_1	.0007629808	13	.00049835690	.00013821933
	Frms_1	.0007303077	13	.00033884774	.00009397945
Pair 6	Arms_1	.0008649582	11	.00047978267	.00014465992
	Grms_1	.0008	11	.00051	.00016
Pair 7	Arms_1	.0008225321	14	.00046792063	.00012505705
	Hrms_1	.0006167993	14	.00043776191	.00011699679
Pair 8	Arms_4	.0008618062	13	.00049243376	.00013657655
	Brms_4	.0006445038	13	.00037037314	.00010272303
Pair 9	Arms_4	.0008886021	14	.00044188365	.00011809837

	Crms_4	.0008149186	14	.00053700020	.00014351934
Pair 10	Arms_4	.0009417617	12	.00045665797	.00013182580
	Drms_4	.0008	12	.00037	.00011
Pair 11	Arms_4	.0009177254	13	.00044572314	.00012362136
	Erms_4	.0007507731	13	.00030194553	.00008374462
Pair 12	Arms_4	.0008416000	11	.00039257566	.00011836602
	Frms_4	.0010168736	11	.00061676566	.00018596184
Pair 13	Arms_4	.0009177254	13	.00044572314	.00012362136
	Grms_4	.0010018469	13	.00043811680	.00012151174
Pair 14	Arms_4	.0008810946	13	.00047274839	.00013111681
	Hrms_4	.0007807092	13	.00046013240	.00012761777
Pair 15	Afrq_1	31.000	14	12.8288	3.4286
	Bfrq_1	26.6071	14	10.02915	2.68040
Pair 16	Afrq_1	30.036	14	11.0427	2.9513
	Cfrq_1	28.79	14	13.344	3.566
Pair 17	Afrq_1	32.821	14	13.5044	3.6092
	Dfrq_1	27.96	14	10.855	2.901
Pair 18	Afrq_1	34.192	13	13.0025	3.6062
	Efrq_1	28.500	13	15.1327	4.1971
Pair 19	Afrq_1	32.692	13	14.3142	3.9701
	Ffrq_1	24.54	13	9.205	2.553
Pair 20	Afrq_1	33.955	11	14.8247	4.4698
	Gfrq_1	27.7727	11	14.42457	4.34917
Pair 21	Afrq_1	31.500	14	12.9020	3.4482
	Hfrq_1	20.786	14	3.9551	1.0570
Pair 22	Afrq_4	33.58	13	15.366	4.262
	Bfrq_4	28.885	13	11.4531	3.1765
Pair 23	Afrq_4	31.46	14	15.439	4.126
	Cfrq_4	29.536	14	12.7919	3.4188
Pair 24	Afrq_4	33.38	12	15.926	4.597
	Dfrq_4	27.0417	12	10.15440	2.93132
Pair 25	Afrq_4	32.27	13	15.761	4.371
	Efrq_4	29.731	13	9.5189	2.6401
Pair 26	Afrq_4	30.82	11	14.033	4.231
	Ffrq_4	24.55	11	4.932	1.487
Pair 27	Afrq_4	32.27	13	15.761	4.371
	Gfrq_4	24.692	13	11.5840	3.2128
Pair 28	Afrq_4	32.23	13	15.755	4.370
	Hfrq_4	25.58	13	6.797	1.885

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Arms_1 & Brms_1	14	.069	.814
Pair 2	Arms_1 & Crms_1	14	.063	.831
Pair 3	Arms_1 & Drms_1	14	.709	.004
Pair 4	Arms_1 & Erms_1	13	-.225	.460
Pair 5	Arms_1 & Frms_1	13	.314	.296
Pair 6	Arms_1 & Grms_1	11	-.192	.573
Pair 7	Arms_1 & Hrms_1	14	.544	.044
Pair 8	Arms_4 & Brms_4	13	.383	.197
Pair 9	Arms_4 & Crms_4	14	-.047	.874
Pair 10	Arms_4 & Drms_4	12	.357	.255
Pair 11	Arms_4 & Erms_4	13	.340	.256
Pair 12	Arms_4 & Frms_4	11	.590	.056
Pair 13	Arms_4 & Grms_4	13	.598	.031
Pair 14	Arms_4 & Hrms_4	13	.756	.003
Pair 15	Afrq_1 & Bfrq_1	14	-.298	.300
Pair 16	Afrq_1 & Cfrq_1	14	.174	.552
Pair 17	Afrq_1 & Dfrq_1	14	.106	.718
Pair 18	Afrq_1 & Efrq_1	13	-.029	.926
Pair 19	Afrq_1 & Ffrq_1	13	.083	.787
Pair 20	Afrq_1 & Gfrq_1	11	.144	.673
Pair 21	Afrq_1 & Hfrq_1	14	.219	.451
Pair 22	Afrq_4 & Bfrq_4	13	.245	.420
Pair 23	Afrq_4 & Cfrq_4	14	-.213	.465
Pair 24	Afrq_4 & Dfrq_4	12	-.205	.523
Pair 25	Afrq_4 & Efrq_4	13	-.248	.413
Pair 26	Afrq_4 & Ffrq_4	11	.049	.887
Pair 27	Afrq_4 & Gfrq_4	13	.564	.045
Pair 28	Afrq_4 & Hfrq_4	13	.471	.104

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Arms_1 - Brms_1	.00010823857	.00056218047	.00015024905	-.00021635477	.00043283191	.720	13	.484
Pair	Arms_1 -	.00000974857	.00067246693	.00017972435	-	.00039801942	.054	13	.958

2	**Crms_1**				.00037852227				
Pair 3	**Arms_1 - Drms_1**	-.00002013786	.00038285270	.00010232169	-.00024119042	.00020091471	-.197	13	.847
Pair 4	**Arms_1 - Erms_1**	-.00026754000	.00081738018	.00022670047	-.00076147790	.00022639790	-1.180	12	.261
Pair 5	**Arms_1 - Frms_1**	.00003267308	.00050704594	.00014062924	-.00027373172	.00033907787	.232	12	.820
Pair 6	**Arms_1 - Grms_1**	.00002977273	.00076765684	.00023145725	-.00048594616	.00054549161	.129	10	.900
Pair 7	**Arms_1 - Hrms_1**	.00020573286	.00043326778	.00011579569	-.00004442851	.00045589423	1.777	13	.099
Pair 8	**Arms_4 - Brms_4**	.00021730231	.00049004292	.00013591345	-.00007882766	.00051343228	1.599	12	.136
Pair 9	**Arms_4 - Crms_4**	.00007368357	.00071114706	.00019006205	-.00033692052	.00048428766	.388	13	.705
Pair 10	**Arms_4 - Drms_4**	.00016803500	.00047613645	.00013744875	-.00013448767	.00047055767	1.223	11	.247
Pair 11	**Arms_4 - Erms_4**	.00016695231	.00044545139	.00012354599	-.00010223127	.00043613589	1.351	12	.202
Pair 12	**Arms_4 - Frms_4**	-.00017527364	.00049868900	.00015036039	-.00051029747	.00015975019	-1.166	10	.271
Pair 13	**Arms_4 - Grms_4**	-.00008412154	.00039645423	.00010995662	-.00032369643	.00015545336	-.765	12	.459
Pair 14	**Arms_4 - Hrms_4**	.00010038538	.00032584875	.00009037418	-.00009652305	.00029729381	1.111	12	.288
Pair 15	**Afrq_1 - Bfrq_1**	4.39286	18.49239	4.94230	-6.28433	15.07004	.889	13	.390
Pair 16	**Afrq_1 - Cfrq_1**	1.2500	15.7709	4.2149	-7.8558	10.3558	.297	13	.771
Pair 17	**Afrq_1 - Dfrq_1**	4.8571	16.4029	4.3839	-4.6136	14.3279	1.108	13	.288
Pair 18	**Afrq_1 - Efrq_1**	5.6923	20.2336	5.6118	-6.5347	17.9193	1.014	12	.330
Pair 19	**Afrq_1 - Ffrq_1**	8.1538	16.3623	4.5381	-1.7338	18.0415	1.797	12	.098
Pair 20	**Afrq_1 - Gfrq_1**	6.18182	19.14063	5.77112	-6.67703	19.04067	1.071	10	.309
Pair 21	**Afrq_1 - Hfrq_1**	10.7143	12.6380	3.3777	3.4173	18.0113	3.172	13	.007
Pair 22	**Afrq_4 - Bfrq_4**	4.6923	16.7637	4.6494	-5.4379	14.8225	1.009	12	.333
Pair 23	**Afrq_4 - Cfrq_4**	1.9286	22.0488	5.8928	-10.8020	14.6592	.327	13	.749
Pair 24	**Afrq_4 - Dfrq_4**	6.33333	20.56733	5.93728	-6.73453	19.40119	1.067	11	.309
Pair 25	**Afrq_4 - Efrq_4**	2.5385	20.3362	5.6402	-9.7506	14.8275	.450	12	.661

Pair 26	**Afrq_4 - Ffrq_4**	6.273	14.646	4.416	-3.567	16.112	1.420	10	.186
Pair 27	**Afrq_4 - Gfrq_4**	7.5769	13.2867	3.6851	-.4521	15.6060	2.056	12	.062
Pair 28	**Afrq_4 - Hfrq_4**	6.654	13.914	3.859	-1.754	15.062	1.724	12	.110